Bacteria Total Maximum Daily Load (TMDL) Development for Tributaries to the Potomac River: Prince William and Stafford Counties

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Executive Summary

This report presents the development of bacteria TMDLs for the Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run watersheds. These waterbodies were listed as impaired on Virginia's 303(d) Total Maximum Daily Load Priority List and Reports (VADEQ, 2010) because of exceedances of the state's water quality criteria for *E. coli* bacteria.

Description of the Study Area

The Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run watersheds are located within the borders of Stafford County and Prince William County. All streams are tributaries to the Potomac River. These watersheds occupy a combined drainage area of 197 square miles.

Impairment Description

Powells Creek (TMDL ID VAN-A26R-02) was first identified as impaired on VA DEQ's 2004 303 (d) Total Maximum Daily Load Priority List due to exceedances for the state's water quality criteria for Fecal Coliform bacteria. In 2006 Powells Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. The segment extends for 4.62 miles, beginning approximately 0.2 rivermiles below Lake Montclair and continuing downstream until the end of the free-flowing waters of Powells Creek.

Quantico Creek (TMDL ID: VAN-A26R-03) was first identified as impaired on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List (VA DEQ, 2004) due to exceedances for the state's water quality criteria for Fecal Coliform bacteria. In 2006 Quantico Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. The bacteria impaired portion of Quantico Creek is 1.45 rivermiles in length, beginning at the confluence with South Fork Quantico Creek, approximately 0.75 rivermiles upstream from I-

95, and continuing downstream until the start of the tidal waters of Quantico Bay. Quantico Creek is located in Prince William County.

South Fork Quantico Creek (TMDL ID: VAN-A26R-03) was first identified as impaired on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List (VA DEQ, 2004) due to exceedances for the state's water quality criterion for *E. Coli* bacteria. The bacteria impaired portion of South Fork Quantico Creek is 4.63 miles in length, beginning at the headwaters of the South Fork Quantico Creek and continuing downstream until the start of the impounded waters, adjacent to what is labeled as Mawavi Camp No. 2 on the Joplin quad. South Fork Quantico Creek is located in Prince William County.

North Branch Chopawamsic Creek segment (TMDL ID: VAN-A26R-04) was first identified as impaired for bacteria on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for *E. coli* bacteria. The impaired segment is 6.9 miles long, beginning at the headwaters of North Branch Chopawamsic Creek and continuing downstream until the confluence with Middle Branch. The North Branch Chopawamsic Creek watershed is located in Prince William and Stafford Counties.

The Unnamed Tributary to Potomac River (TMDL ID: A26R-07-BAC) was first identified as impaired for bacteria on VADEQ's 2010 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for *E. coli* bacteria. The segment is 0.79 miles long, beginning at the headwaters of the Unnamed Tributary (Stream Code XLF) and continuing downstream until its confluence with the Potomac River. The Unnamed Tributary to the Potomac River is located in Stafford County.

Austin Run (TMDL ID: VAN-A28R-01) was first identified as impaired for bacteria on VA DEQ's 2004 303 (d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for fecal coliform bacteria. The impaired portion of Austin Run is 0.79 miles long, beginning at the confluence with an unnamed tributary to Austin Run (streamcode XGQ) and continuing downstream until the confluence with Aquia Creek. Austin Run is located in Stafford County.

A portion of Accokeek Creek (TMDL ID: VAN-A29R-01) was first identified as impaired for bacteria on VA DEQ's 2002 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criteria for Fecal Coliform criteria. In 2006 Accokeek Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. The impaired portion of Accokeek Creek is approximately 4.21 rivermiles long, beginning at the confluence with an unnamed tributary to Accokeek Creek, approximately 0.33 rivermile downstream from Route 1 at rivermile 8.62, and continuing downstream until the end of the free-flowing waters. Accokeek Creek is located in Stafford County.

Potomac Creek (TMDL ID: VAN-A29R-02) was first identified as impaired for bacteria on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for fecal coliform bacteria. In 2006 Potomac Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. The impaired portion of Potomac Creek is approximately 2.18 rivermiles long, beginning at the railroad crossing at the west end of swamp upstream from Route 608, and continuing downstream until the east end of the swamp. Potomac Creek is located in Stafford County.

Potomac Run (TMDL ID: 60073) was first identified as impaired on VA DEQ's 2006 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for *E. coli* bacteria. The impaired portion of Potomac Run is approximately 6.13 miles long, beginning at the headwaters of Potomac Run and continuing downstream until the confluence with Long Branch. Potomac Run is located in Stafford County.

Applicable Water Quality Standards

Virginia's bacteria water quality standard currently states that *E. coli* bacteria shall not exceed a geometric mean of 126 *E. coli* counts per 100 mL of water for four weekly samples within a calendar month. In the event that sufficient samples are not taken to calculate a geometric mean, no more than 10 percent of the *E. coli* samples shall exceed a concentration of 235 counts per 100 mL during an assessment period. However, the loading rates for watershed-based modeling are available only in terms of the previous standard, fecal coliform bacteria. Therefore, the TMDL was expressed in *E. coli* by converting modeled daily fecal coliform concentrations to daily *E. coli* concentrations using an instream translator. This TMDL was required to meet both the geometric mean and maximum assessment criteria for *E. coli* bacteria.

Watershed Characterization

The land use characterization for the Tributaries to the Potomac River: Prince William and Stafford County watersheds were based on land cover data from the 2006 National Land Cover Database (NLCD). Dominant land uses in the watersheds are Forest (64%) and Developed (12%).

The potential sources of bacteria in the watershed were identified and characterized. Potential key sources of bacteria include run-off from point source dischargers, pet waste, residential waste, livestock, and wildlife sources.

Data obtained from VADEQ's Northern Regional Office indicate that there are two individually permitted Virginia Pollutant Discharge Elimination System (VPDES) facilities currently permitted within the Austin Run watershed (VA0092479 and VA0060968), two VPDES facilities currently permitted in the Accokeek Creek watershed (VA0089630 and VAG406207) and one VPDES facility permitted within the Unnamed Tributary to Potomac River watershed (VAG406114). The available flow data and water quality for the permitted facilities was retrieved and analyzed. Average flows for the permitted facilities were used in the HSPF model set-up and calibration. In addition to VPDES permitted facilities, 7 Municipal Separate Storm Sewer System (MS4) permitted entities were included in these TMDLs.

TMDL Technical Approach

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the instream water quality conditions of the delineated watershed under varying scenarios of rainfall and fecal coliform loading. HSPF is a hydrologic, watershed-based water quality model. The results from the model were used to develop the TMDL allocations based on the existing fecal coliform load. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

The Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run watersheds were delineated into 56 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on a Digital Elevation Model (DEM), stream reaches obtained from the National Hydrography Dataset (NHD), and stream flow and instream water quality data. Stream flow data were available from the U.S. Geological Survey (USGS). Weather data were obtained from the National Climatic Data Center (NCDC).

The period of 2002 to 2005 was used for HSPF hydraulic calibration and 2006 to 2010 was used to validate the HSPF model. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Instream water quality data for the calibration was retrieved from VADEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. The existing *E. coli* loading was calculated based on current watershed conditions.

TMDL Calculations

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated in this TMDL. Implicitly incorporating the MOS required that allocation scenarios be designed to meet a calendar-month geometric mean *E. coli* criterion of 126 cfu/100 mL and the maximum assessment *E. coli* criterion of 235 cfu/100 mL with no more than a 10% exceedance rate.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

Based on the load-allocation scenario analyses, the TMDL allocation plans that will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 mL and the maximum assessment *E. coli* water quality criterion of 235 cfu/100 mL are presented in **Tables E-1** to **E-9**.

Table E-1: Powells Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	1.49E+13	2.33E+12	84.4%
Cropland	1.44E+12	2.88E+10	98.0%
Pasture	1.36E+13	2.72E+11	98.0%
Urban	1.15E+14	2.30E+12	98.0%
Cattle-Direct Deposition	2.09E+12	0.00E+00	100.0%
Wildlife-Direct Deposition	2.62E+12	2.62E+12	0.0%
Failing Sewage Disposal Systems	4.04E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	7.55E+10	-
Total	**1.50E+14**	**7.63E+12**	**94.9%**

Table E-2: Quantico Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	7.59E+12	7.59E+12	0.0%
Cropland	6.88E+10	9.64E+08	98.6%
Pasture	4.21E+10	5.89E+08	98.6%
Urban	8.64E+13	1.21E+12	98.6%
Cattle-Direct Deposition	2.34E+10	0.00E+00	100.0%
Wildlife-Direct Deposition	2.47E+12	2.47E+12	0.0%
Failing Sewage Disposal Systems	1.37E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	1.13E+11	-
Total	**9.67E+13**	**1.14E+13**	**88.2%**

Table E-3: South Fork Quantico Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	6.09E+12	1.46E+12	76.0%
Cropland	1.78E+09	8.92E+07	95.0%
Pasture	3.94E+08	1.97E+07	95.0%
Urban	1.83E+11	9.15E+09	95.0%
Cattle-Direct Deposition	2.37E+11	0.00E+00	100.0%
Wildlife-Direct Deposition	1.30E+12	1.30E+12	0.0%
Failing Sewage Disposal Systems	5.52E+09	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	2.77E+10	-
Total	**7.82E+12**	**2.80E+12**	**64.2%**

Table E-4: North Branch Chopawamsic Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	2.60E+13	1.66E+12	93.6%
Cropland	1.98E+09	1.26E+08	93.6%
Pasture	4.15E+08	2.65E+07	93.6%
Urban	5.93E+11	3.79E+10	93.6%
Cattle-Direct Deposition	0.00E+00	0.00E+00	0.0%
Wildlife-Direct Deposition	2.12E+12	2.12E+12	0.0%
Failing Sewage Disposal Systems	0.00E+00	0.00E+00	0.0%
Permitted Point Sources	0.00E+00	3.82E+10	-
Total	**2.87E+13**	**3.86E+12**	**86.6%**

Table E- 5: Unnamed Tributary to Potomac River Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	5.17E+12	2.90E+11	94.4%
Cropland	1.70E+09	9.50E+07	94.4%
Pasture	1.07E+09	5.98E+07	94.4%
Urban	3.90E+12	2.19E+11	94.4%
Cattle-Direct Deposition	1.08E+09	0.00E+00	100.0%
Wildlife-Direct Deposition	6.90E+11	6.90E+11	0.0%
Failing Sewage Disposal Systems	7.45E+10	0.00E+00	100.0%
Permitted Point Sources	1.74E+09	1.37E+10	-
Total	**9.84E+12**	**1.21E+12**	**87.7%**

Table E- 6: Austin Run Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	4.33E+13	1.78E+12	95.9%
Cropland	7.42E+09	3.04E+08	95.9%
Pasture	2.88E+09	1.18E+08	95.9%
Urban	3.36E+13	1.38E+12	95.9%
Cattle-Direct Deposition	2.48E+10	0.00E+00	100.0%
Wildlife-Direct Deposition	1.67E+12	1.67E+12	0.0%
Failing Sewage Disposal Systems	1.04E+11	0.00E+00	100.0%
Permitted Point Sources	7.87E+12	3.13E+13	-
Total	8.66E+13	3.62E+13	58.2%

Table E- 7: Accokeek Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation			
Land Use/Source	**Average *E. coli* Loads (cfu/yr)**		**Percent Reduction (%)**
	Existing	**Allocation**	
Forest	7.24E+12	2.50E+12	65.5%
Cropland	5.52E+11	2.49E+10	95.5%
Pasture	1.01E+13	4.53E+11	95.5%
Urban	4.24E+13	1.91E+12	95.5%
Cattle-Direct Deposition	1.40E+12	0.00E+00	100.0%
Wildlife-Direct Deposition	1.73E+12	1.73E+12	0.00%
Failing Sewage Disposal Systems	1.33E+11	0.00E+00	100.00%
Permitted Point Sources	3.13E+09	6.93E+10	-
Total	**6.36E+13**	**6.69E+12**	**89.48%**

Table E- 8: Potomac Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation			
Land Use/Source	**Average *E. coli* Loads (cfu/yr)**		**Percent Reduction (%)**
	Existing	**Allocation**	
Forest	5.61E+13	4.37E+12	92.2%
Cropland	7.27E+12	5.67E+11	92.2%
Pasture	3.26E+13	2.54E+12	92.2%
Urban	4.44E+13	3.46E+12	92.2%
Cattle-Direct Deposition	5.37E+12	0.00E+00	100.0%
Wildlife-Direct Deposition	1.21E+11	1.21E+11	0.00%
Failing Sewage Disposal Systems	2.18E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	1.11E+11	0.0%
Total	**1.46E+14**	**1.12E+13**	**92.4%**

Table E- 9: Potomac Run Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation			
Land Use/Source	**Average *E. coli* Loads (cfu/yr)**		**Percent Reduction (%)**
	Existing	**Allocation**	
Forest	1.31E+13	2.62E+11	98.0%
Cropland	4.14E+12	8.28E+10	98.0%
Pasture	3.64E+13	7.28E+11	98.0%
Urban	2.63E+12	5.26E+10	98.0%
Cattle-Direct Deposition	2.19E+13	0.00E+00	100.0%
Wildlife-Direct Deposition	2.17E+12	8.88E+11	59.0%
Failing Sewage Disposal Systems	2.16E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	2.01E+10	0.0%
Total	**8.06E+13**	**2.03E+12**	**97.5%**

The summaries of the bacteria TMDL allocation plan loads are presented in the flowing tables.

The bacteria TMDLs for Powells Creek are presented in **Tables E-10** and **E-11**.

Table E- 10: Powells Creek TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Powells Creek	**2.38E+12**	**5.25E+12**	**IMPLICIT**	**7.63E+12**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

Table E- 11: Powells Creek TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Powells Creek	**2.07E+08**	**7.58E+10**	**IMPLICIT**	**7.60E+10**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

The bacteria TMDLs for Quantico Creek are presented in **Tables E-12** and **E-13**.

Table E- 12: Quantico Creek TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Quantico Creek	**1.32E+12**	**1.01E+13**	**IMPLICIT**	**1.14E+13**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

Table E- 13: Quantico Creek TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Quantico Creek	**3.09E+08**	**1.13E+11**	**IMPLICIT**	**1.14E+11**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

The bacteria TMDLs for South Fork Quantico Creek are presented in **Tables E-14** and **E-15**.

Table E- 14: South Fork Quantico Creek TMDLs (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
South Fork Quantico Creek	**3.69E+10**	**2.76E+12**	**IMPLICIT**	**2.80E+12**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

Table E- 15: South Fork Quantico Creek TMDLs (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
South Fork Quantico Creek	**7.59E+07**	**2.78E+10**	**IMPLICIT**	**2.79E+10**

[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).

The bacteria TMDLs for North Branch Chopawamsic Creek are presented in **Tables E-16** and **E-17**.

Table E- 16: North Branch Chopawamsic Creek TMDLs (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
North Branch Chopawamsic Creek	**7.36E+10**	**3.78E+12**	**IMPLICIT**	**3.86E+12**

[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).

Table E- 17: North Branch Chopawamsic Creek TMDLs (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
North Branch Chopawamsic Creek	**1.05E+08**	**4.01E+10**	**IMPLICIT**	**4.02E+10**

[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).

The bacteria TMDLs for Unnamed Tributary to Potomac River are presented in **Tables E-18** and **E-19**.

Table E- 18: Unnamed Tributary to Potomac River TMDLs (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Unnamed Tributary to Potomac River	**2.22E+11**	**9.91E+11**	**IMPLICIT**	**1.21E+12**

[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).

Table E- 19: Unnamed Tributary to Potomac River TMDLs (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Unnamed Tributary to Potomac River	**3.28E+07**	**1.20E+10**	**IMPLICIT**	**1.20E+10**

[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).

The bacteria TMDLs for Austin Run are presented in **Tables E-20** and **E-21**.

Table E- 20: Austin Run TMDLs (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Austin Run	**3.22E+13**	**3.93E+12**	**IMPLICIT**	**3.62E+13**
[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).				

Table E- 21: Austin Run TMDLs (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Austin Run	**8.74E+10**	**2.10E+10**	**IMPLICIT**	**1.08E+11**
[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).				

The bacteria TMDLs for Accokeek Creek are presented in **Tables E-22** and **E-23**.

Table E- 22: Accokeek Creek TMDLs (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Accokeek Creek	**2.08E+11**	**6.48E+12**	**IMPLICIT**	**6.69E+12**
[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).				

Table E- 23: Accokeek Creek TMDLs (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Accokeek Creek	**1.81E+08**	**6.76E+10**	**IMPLICIT**	**6.78E+10**
[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).				

The bacteria TMDLs for Potomac Creek are presented in **Tables E-24** and **E-25**.

Table E- 24: Potomac Creek TMDLs (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Potomac Creek	**1.74E+11**	**1.10E+13**	**IMPLICIT**	**1.12E+13**
[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).				

Table E- 25: Potomac Creek TMDLs (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Potomac Creek	**3.03E+08**	**1.16E+11**	**IMPLICIT**	**1.16E+11**
[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).				

The bacteria TMDLs for Potomac Run are presented in **Tables E-26** and **E-27**.

Table E- 26: Potomac Run TMDLs (cfu/year) for *E. coli*

Watershed	WLA[1]	LA	MOS	TMDL
Potomac Run	**6.21E+10**	**1.97E+12**	**IMPLICIT**	**2.03E+12**

[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).

Table E- 27: Potomac Run TMDLs (cfu/day) for *E. coli*

Watershed	WLA[1]	LA	MOS	TMDL
Potomac Run	**5.52E+07**	**1.93E+10**	**IMPLICIT**	**1.93E+10**

[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).

TMDL Implementation

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

A TMDL implementation plan will be developed that addresses, at a minimum, the requirements specified in the Code of Virginia, Section 62.1-44.19.7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments." EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

Introduction

1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that do not meet water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without exceeding water quality standards. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between pollution sources and instream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The Virginia Department of Environmental Quality (VADEQ) is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. VADEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and regulate a more effective TMDL process. VADEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA), passed by the Virginia General Assembly in 1997, and coordinates public participation throughout the TMDL development process.

Within the context of the TMDL program, a primary role of DCR is to regulate stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the Virginia Stormwater Management Program (VSMP). Another important role of DCR is to initiate non-point source pollution control programs statewide through the use of federal grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (VADEQ, 2001).

As required by the Clean Water Act and WQMIRA, VADEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters. In addition to 303(d) List development, WQMIRA directs VADEQ to develop and implement TMDLs for listed waters (VADEQ, 2000). Once TMDLs have been developed, they are distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Segments of Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, an Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek, and Potomac Run were listed as impaired for bacteria on Virginia's 2002, 2004, 2006, 2008 and/or 2010 303(d) Total Maximum Daily Load Priority List and Reports due to exceedances of the state's water quality standard for bacteria. The impaired segments are located in hydrologic units 02070011 and include portions of Stafford and Prince William Counties.

All segments are riverine. **Table 1-1** summarizes the details of the impaired segments and **Figure 1-1** presents their location. Descriptions of the impaired segment watersheds are presented below.

1.2.1 Powells Creek

Powells Creek (TMDL ID VAN-A26R-02) was first identified as impaired on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for Fecal Coliform bacteria. In 2006 Powells Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. The segment extends for 4.62 miles, beginning approximately 0.2 rivermiles below Lake Montclair and continuing downstream until the end of the free-flowing waters of Powells Creek. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 2 out of 13 samples (15%) exceeded the maximum water quality assessment criterion (235 cfu/100ml) for *E. coli* bacteria at Station1aPOW006.11. Station 1aPOW006.11 is located at the Northgate Drive bridge crossing. Powells Creek is located in Prince William County.

1.2.2 Quantico Creek and South Fork Quantico Creek

Quantico Creek (TMDL ID: VAN-A26R-03) was first identified as impaired on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List (VA DEQ, 2004) due to exceedances for the state's water quality criterion for Fecal Coliform bacteria. In 2006 Quantico Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. South Fork Quantico Creek (TMDL ID: VAN-A26R-03) was first identified as impaired on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List (VA DEQ, 2004) due to exceedances for the state's water quality criterion for *E. Coli* bacteria.

The bacteria impaired portion of Quantico Creek is 1.45 rivermiles in length, beginning at the confluence with South Fork Quantico Creek, approximately 0.75 rivermiles upstream from I-95, and continuing downstream until the start of the tidal waters of Quantico Bay. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 7 out of 27 samples (26%) exceeded the maximum water quality assessment criterion (235 cfu/100ml) for *E. coli* bacteria at Station1aQUA004.46. Station 1aQUA004.46 is located at the Route 1 (Business) bridge crossing. Quantico Creek is located in Prince William County.

The bacteria impaired portion of South Fork Quantico Creek is 4.63 miles in length, beginning at the headwaters of South Fork Quantico Creek and continuing downstream until the start of the impounded waters, adjacent to what is labeled as Mawavi Camp No. 2 on the Joplin quad. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 7 out of 47 samples (15%) exceeded the maximum water quality criterion (235 cfu/100ml) for *E. coli* bacteria at USGS Station 01658500. South Fork Quantico Creek is located in Prince William County.

1.2.3 North Branch Chopawamsic Creek

North Branch Chopawamsic Creek segment (TMDL ID: VAN-A26R-04) was first identified as impaired for bacteria on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for *E. coli* bacteria. The impaired segment is 6.9 miles long, beginning at the headwaters of North Branch Chopawamsic Creek and continuing downstream until the confluence with Middle Branch. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 2 out of 17 samples (12%) exceeded the maximum water quality assessment criterion (235 cfu/100ml) for *E. coli* bacteria at USGS Station 01659000. The North Branch Chopawamsic Creek watershed is located in Prince William and Stafford Counties.

1.2.4 Unnamed Tributary to the Potomac River

The Unnamed Tributary to Potomac River (TMDL ID: A26R-07-BAC) was first identified as impaired for bacteria on VADEQ's 2010 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for *E. coli* bacteria. The segment is 2.9 miles long, beginning at the headwaters of the Unnamed Tributary (Stream Code XLF) and continuing downstream until its confluence with the Potomac River. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 2 of 11 *E. coli* samples (18%) exceeded the maximum water quality assessment criteria (235 cfu/100 ml) for *E. coli* bacteria at Station 1aXLF000.13. Station 1aXLF000.13 is located at the Route 633 bridge crossing. The Unnamed Tributary to the Potomac River is located in Stafford County.

1.2.5 Austin Run

Austin Run (TMDL ID: VAN-A28R-01) was first identified as impaired for bacteria on VA DEQ's 2004 303 (d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for fecal coliform bacteria. The impaired portion of Austin Run is 0.79 miles long, beginning at the confluence with an unnamed tributary to Austin Run (streamcode XGQ) and continuing downstream until the confluence with Aquia Creek. Based on monitoring data for the 2006 Water Quality Assessment (January 1, 2000 to December 31, 2004) 3 of 8 samples (38%) exceeded the maximum criterion (400 MPN/100 ml) for fecal coliform bacteria at Station 1aAUS000.49 on Austin Run. Station 1aAUS000.49 is located near the end of Aquia Drive. Austin Run is located in Stafford County.

1.2.6 Accokeek Creek

A portion of Accokeek Creek (TMDL ID: VAN-A29R-01) was first identified as impaired for bacteria on VA DEQ's 2002 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criteria for Fecal Coliform criteria. In 2006 Accokeek

Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. The impaired portion of Accokeek Creek is approximately 4.21 rivermiles long, beginning at the confluence with an unnamed tributary to Accokeek Creek, approximately 0.33 rivermiles downstream from Route 1 at rivermile 8.62, and continuing downstream until the end of the free-flowing waters. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 4 of 23 samples (17.4%) exceeded the maximum water quality assessment criterion (235 cfu/100 ml) for *E. coli* bacteria at Station 1aACC006.13. Station 1aACC006.13 is located at the Route 608 bridge crossing. Accokeek Creek is located in Stafford County.

1.2.7 Potomac Creek and Potomac Run

Potomac Creek (TMDL ID: VAN-A29R-02) was first identified as impaired for bacteria on VA DEQ's 2004 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for fecal coliform bacteria. In 2006 Potomac Creek was listed as impaired due to exceedances of the state's water quality criterion for *E. coli* bacteria. Potomac Run (TMDL ID: 60073) was first identified as impaired on VA DEQ's 2006 303(d) Total Maximum Daily Load Priority List due to exceedances of the state's water quality criterion for *E. coli* bacteria.

The impaired portion of Potomac Creek is approximately 2.18 rivermiles long, beginning at the railroad crossing at the west end of swamp upstream from Route 608, and continuing downstream until the east end of the swamp. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 4 of 13 samples (31%) exceeded the maximum water quality criterion (235 cfu/100 ml) for *E. coli* bacteria at Station 1aPOM006.72. Station 1aPOM006.72 is located at the Route 608 bridge crossing. Potomac Creek is located in Stafford County.

The impaired portion of Potomac Run is approximately 6.13 miles long, beginning at the headwaters of Potomac Run and continuing downstream until the confluence with Long Branch. During the 2010 Water Quality Integrated Assessment period (January 1, 2003 – December 31, 2008) 10 of 13 samples (77%) exceeded the maximum water quality assessment criterion (235 cfu/100 ml) for *E. coli* bacteria at Station 1aPOR000.40. Station

1aPOR000.40 is located at the Route 648 bridge crossing. Potomac Run is located in Stafford County.

Table 1- 1: Impairment Summary

TMDL ID	Assessment Unit	Stream Name	Length (miles)	Boundaries	Listing Station ID:	Cause:	Exceedance Rate*
VAN-A26R-02	VAN-A26R_POW01A00	Powells Creek	4.62	Approximately 0.2 rivermiles below Lake Montclair downstream until the end of the free-flowing waters of Powells Creek.	1aPOW006.11	*E. coli*	2 of 13 samples (15.4%)
VAN-A26R-03	VAN-A26R_QUA01A00	Quantico Creek	1.45	Confluence with South Fork Quantico Creek downstream until the start of the tidal waters of Quantico Bay.	1aQUA004.46	*E. coli*	7 of 27 samples (26%)
VAN-A26R-03	VAN-A26R_SOQ01B02	South Fork Quantico Creek	4.63	Headwaters of the South Fork Quantico Creek downstream until the start of the impounded waters, adjacent to what is labeled as Mawavi Camp No. 2 on the Joplin Quad.	01658500 (USGS)	*E. coli*	7 of 47 samples (15%)
VAN-A26R-04	VAN-A26R_NOR01A02	North Branch Chopawamsic Creek	6.9	Headwaters of North Branch Chopawamsic Creek downstream until the confluence with Middle Branch	01659000 (USGS)	*E. coli*	2 of 17 samples (12%)
VAN-A26R-07-BAC	VAN-A26R_XLF01A10	Unnamed tributary to Potomac River	2.9	Headwaters of the unnamed tributary downstream until its confluence with the Potomac River	1aXLF000.13	*E. coli*	2 of 11 samples (18%)
VAN-A28R-01	VAN-A28R_AUS01A04	Austin Run	0.79	Confluence with an unnamed tributary to Austin Run (streamcode XGQ) downstream until the confluence with Aquia Creek	1aAUS000.49	*E. coli*	2 of 10 samples (20%)**

*Exceedance rate listed in Virginia's 2010 305(b)/303(d) Water Quality Integrated Assessment
**Exceedance rate listed in Virginia's 2006 305(b)/303(d) Water Quality Integrated Assessment

Table 1-1: Impairment Summary for Lower Potomac NRO Waterbodies

TMDL ID	Assessment Unit	Stream Name	Length (miles)	Boundaries	Listing Station ID	Cause	Exceedance Rate*
VAN-A29R-01	VAN-A29R_ACC01A00	Accokeek Creek	4.21	Confluence with an unnamed tributary to Accokeek Creek (rivermile 8.62) located approximately 0.33 rivermiles downstream from Route 1, downstream until the end of the free-flowing waters.	1aACC006.13	*E. coli*	4 of 23 samples (17%)
VAN-A29R-02	VAN-A29R_POM01A00	Potomac Creek	2.18	Railroad crossing at the west end of swamp, upstream from Route 608, downstream until the east end of swamp.	1aPOM006.72	*E. coli*	4 of 13 samples (31%)
60073	VAN-A29R_POR01A06	Potomac Run	6.13	Headwaters of Potomac Run downstream until the confluence with Long Branch.	1aPOR000.40	*E. coli*	10 of 13 samples (77%)

*Exceedance rate listed in Virginia's 2010 305(b)/303(d) Water Quality Integrated Assessment

**Exceedance rate listed in Virginia's 2006 305(b)/303(d) Water Quality Integrated Assessment

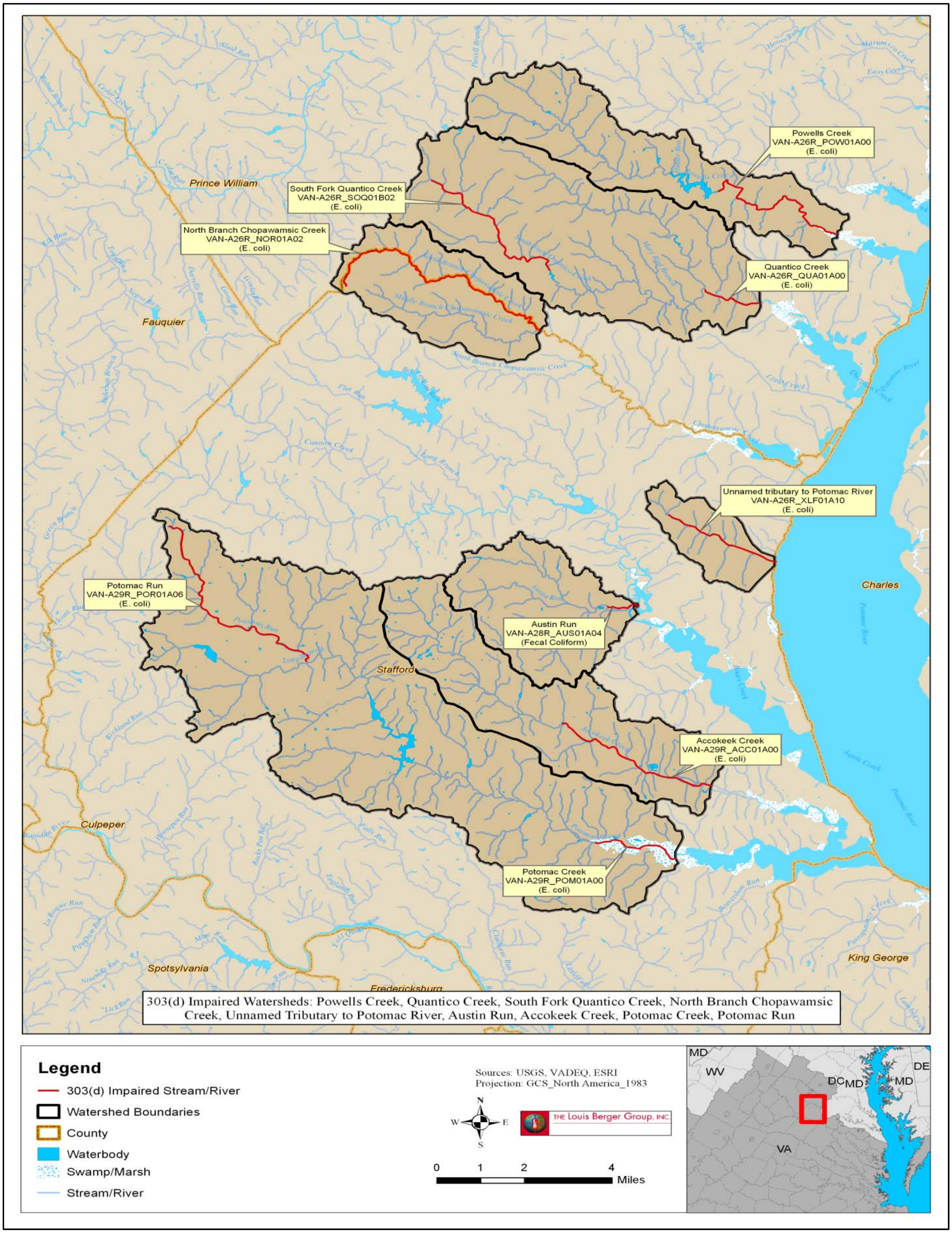

Figure 1- 1: Location of the Bacteria Impaired Segments

1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a waterbody and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term 'water quality standards' is defined as:

"...provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

"...all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."

1.3.2 Applicable Water Quality Criteria

According to Section 9 VAC 25-260-170.A of Virginia's Water Quality Standards (Effective January 6, 2011), for a non-shellfish, freshwater waterbody to be in compliance with Virginia bacteria standards for primary contact recreation, the current criteria are as follows:

"E. coli bacteria shall not exceed a monthly geometric mean of 126 CFU/100 ml in freshwater...Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples... If there are insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E. coli CFU/100 ml."

For bacteria TMDL development after January 15, 2003, *E. coli* is the primary applicable water quality target. However, the loading rates for watershed-based modeling are available only in terms of fecal coliform. Therefore, DCR, DEQ, and EPA have agreed to apply a translator to instream fecal coliform data to determine whether reductions applied to the fecal coliform load would result in meeting instream *E. coli* criteria. The fecal coliform model and instream translator are used to calculate *E. coli* TMDLs (VADEQ, 2003). The following regression based instream translator is used to calculate *E. coli* concentrations from fecal coliform concentrations:

$$\log_2 EC\ (cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC\ (cfu/100mL)$$

Where: EC = E. coli bacteria concentration
FC = Fecal coliform bacteria concentration

The modeled daily fecal coliform concentrations are converted to daily *E. coli* concentrations using the instream translator. The TMDL development process must also account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in exceedances under a wide variety of scenarios that affect bacteria loading.

1.4 TMDL Endpoint Identification

1.4.1 Selection of TMDL Endpoint and Water Quality Targets

One of the first steps in TMDL development is to determine a numeric endpoint, or water quality target, for each impaired segment. A water quality target compares the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the bacteria impaired segments of Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac Creek, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run are established in Virginia Water Quality Standards (9 VAC 25-260). These standards state that all waters in Virginia should be free from any substances that can cause the water to exceed the state numeric criteria, interfere with its designated uses, or adversely affect human health and aquatic life. The current water quality target for freshwater, non-shellfish waters, as stated in 9 VAC 25-260-170, is an *E. coli* geometric mean of no greater than 126 colony-forming units (cfu) per 100 ml (minimum of four weekly samples within a calendar month necessary to calculate the geometric mean), and no more than 10% exceedance of the maximum assessment criterion of 235 cfu per 100mL.

1.4.2 Critical Condition

The critical condition refers to the "worst case scenario" of environmental conditions in the Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac Creek, Austin Run, Accokeek Creek, Potomac Creek, and Potomac Run segments. Developing TMDLs to meet the water quality targets under the critical condition will ensure that the targets would also be met under all other conditions.

EPA regulations, 40 CFR 130.7 (c)(1), require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the impaired streams is protected during times when it is most vulnerable. Critical conditions are important because they describe the combination of factors that cause an exceedance of water quality criteria. They will help in identifying the actions that may have to be undertaken to meet water quality standards.

1.4.2.1 Powells Creek

The dominant land uses in the Powells Creek watershed are forest (47%) and developed (31%). Potential key sources of *E. coli* include run-off from residential waste and wildlife sources.

E. coli loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available instream water quality data and flow data obtained from the nearby USGS flow monitoring station located on Aquia Creek.

The following figure shows the observed level of *E. coli* (**Figure 1-2**) under different flow conditions at VADEQ water quality stations 1APOW003.11 and 1APOW006.11.

The data for flow was obtained from USGS station 01660400, located on Aquia Creek near Garrisonville, VA. **Figure 1-2** depicts *E. coli* concentrations recorded between 2003 and 2010 with the available corresponding stream flow percentile.

E. coli data were available at VADEQ listing stations 1APOW003.11 and 1APOW006.11. The maximum assessment criterion is shown as a thick red line (235 *E. coli*/100 ml of water). Plotting *E. coli* data along with available stream flow data (**Figure 1-2**) revealed that exceedances occurred during high flow, dry, and low flow conditions.

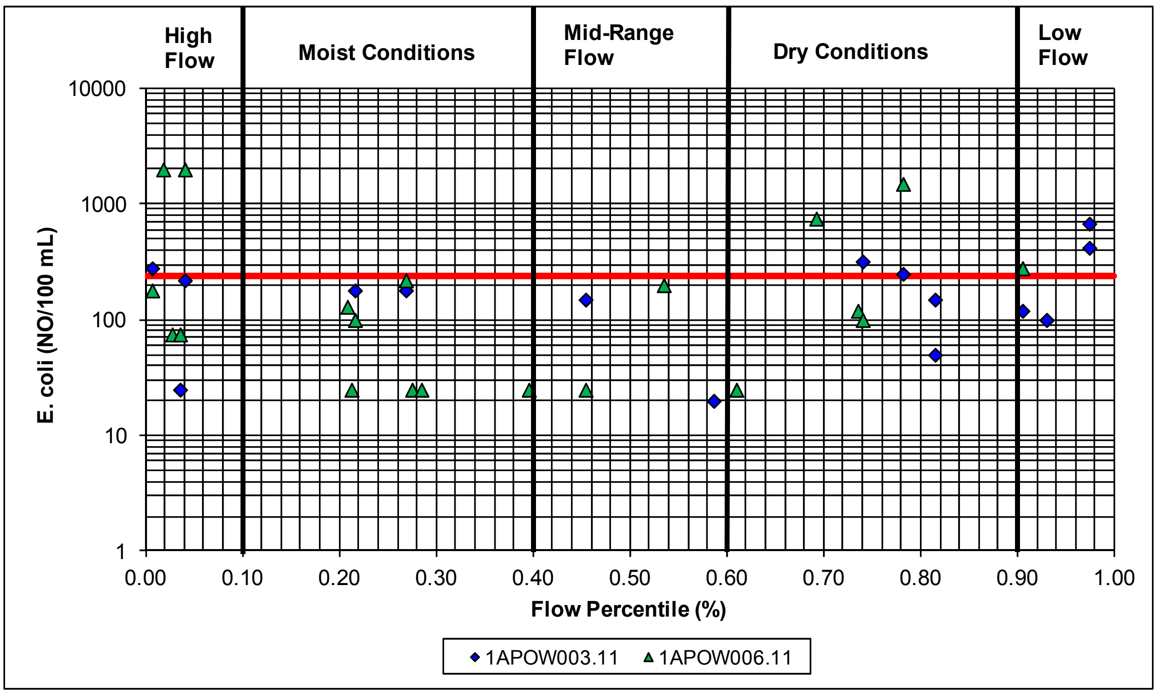

Figure 1- 2: Flow Percentile and *E. coli* Concentrations for Powells Creek at 1APOW003.11 and 1APOW006.11 (2003-2010)

While the majority of exceedances occur in dry and low flow conditions, exceedances do occur in high flow conditions, thus higher flow periods cannot be ruled out. Consequently, both higher and lower flow periods were considered as the critical conditions. Exceedances under high-flow conditions would occur from runoff based, indirect sources of bacteria, and would most likely exceed the maximum assessment criterion. Bacteria loads under low-flow conditions would likely occur from direct deposition sources of bacteria, and would most likely exceed both the maximum assessment and geometric mean criteria.

The TMDL is required to meet both the geometric mean and maximum assessment bacteria criteria. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions, and dry weather, low flow conditions in order to comply with both bacteria criteria.

1.4.2.2 Quantico Creek and South Fork Quantico Creek

The dominant land uses in the Quantico Creek and South Fork Quantico Creek watershed are forest (85%) and developed (7%). Potential key sources of *E. coli* include run-off from residential waste and wildlife sources.

E. coli loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available instream water quality data and flow data obtained from the nearby USGS flow monitoring station located on Aquia Creek.

The following figures show the observed level of *E. coli* under different flow conditions at VADEQ water quality station 1AQUA004.46 (Quantico Creek, **Figure 1-3**) and 1ASOQ006.73 (South Fork Quantico Creek, **Figure 1-4**). The data for flow was obtained from USGS station 01660400, located on Aquia Creek near Garrisonville, VA. **Figure 1-3** depicts *E. coli* concentrations recorded between 2003 and 2010 with the available corresponding stream flow percentile and **Figure 1-4** depicts *E. coli* concentrations recorded in 2010 with the available corresponding stream flow percentile.

E. coli data were available at VADEQ stations 1AQUA004.46, 1ASOQ006.73, and USGS Station 01658500. DEQ Station 1ASOQ006.73 and USGS Station 01658500 are collocated. The maximum assessment criterion is shown as a thick red line (235 *E. coli*/100 ml of water). Plotting *E. coli* data along with available stream flow data revealed that the exceedances occurred during all flow conditions for Quantico Creek (**Figure 1-3**) and all flow conditions for South Fork Quantico Creek (**Figure 1-4**).

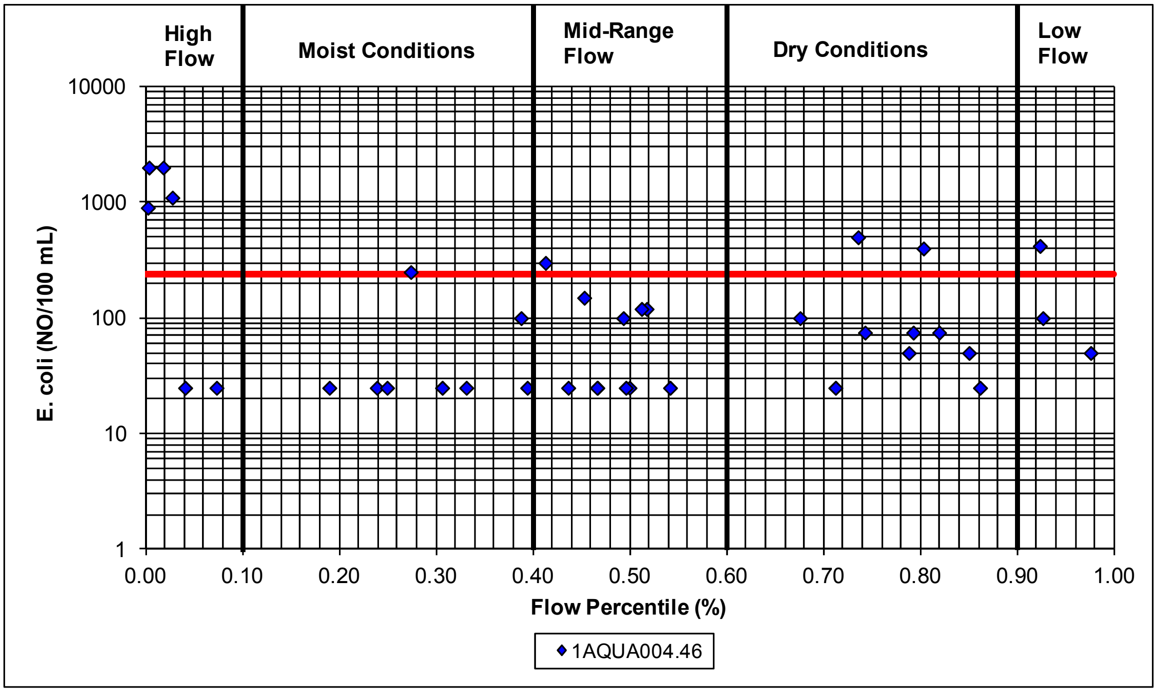

Figure 1-3: Flow Percentile and *E. coli* Concentrations for Quantico Creek at 1AQUA004.46 (2003-2010)

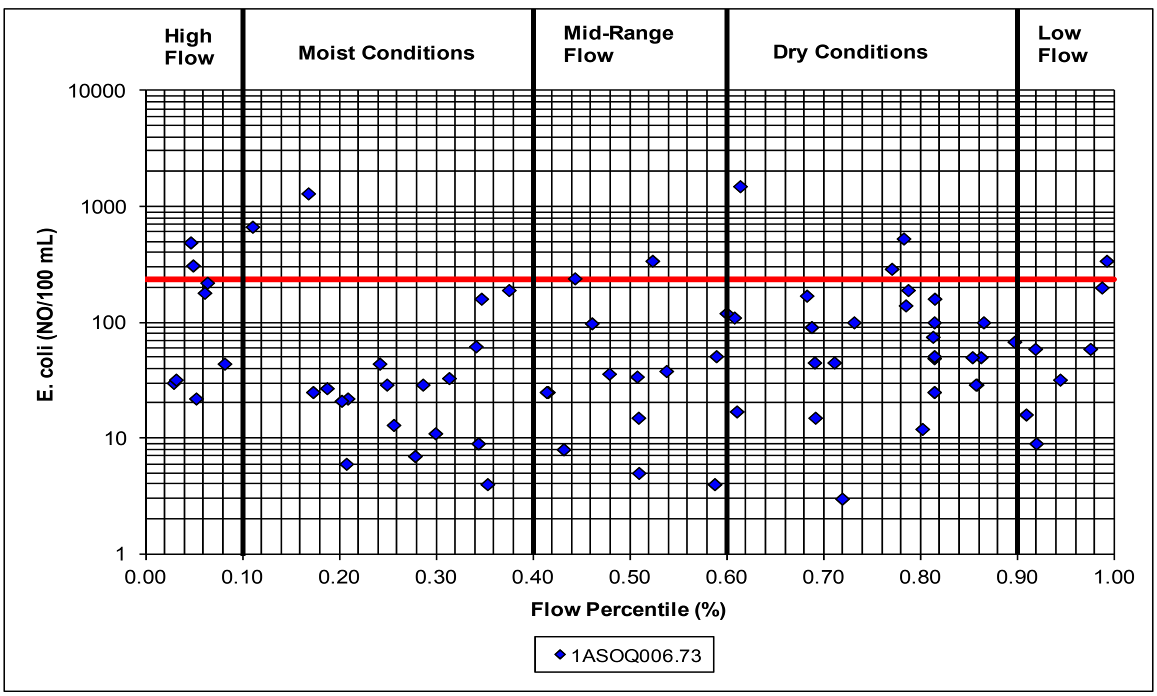

Figure 1-4: Flow Percentile and *E. coli* Concentrations for South Fork Quantico Creek at 1ASOQ006.73 and USGS Station 01659000 (2003 - 2010)

Since exceedances occur in all flow conditions for both Quantico Creek and South Fork Quantico Creek, both higher and lower flow periods were considered as the critical conditions for both impaired segments. Exceedances under high-flow conditions would occur from runoff based, indirect sources of bacteria, and would most likely exceed the maximum assessment criterion. Bacteria loads under low-flow conditions would likely occur from direct deposition sources of bacteria, and would most likely exceed both the maximum assessment and the geometric mean criteria.

The TMDL is required to meet both the bacteria criteria. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both criteria.

1.4.2.3 North Branch Chopawamsic Creek

The dominant land uses in the North Branch Chopawamsic Creek watershed are forest (84%) and wetland (12%). Potential key sources of *E. coli* include run-off from wildlife sources.

E. coli loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available instream water quality data and flow data obtained from the nearby USGS flow monitoring station located on Aquia Creek.

The following figure shows the observed level of *E. coli* under different flow conditions at VADEQ water quality station 1ANOR009.87 and USGS Station 01659000 (**Figure 1-5**). The data for flow was obtained from USGS station 01660400, located on Aquia Creek near Garrisonville, VA. **Figure 1-5** depicts *E. coli* concentrations recorded in 2010 with the available corresponding stream flow percentile.

E. coli data were available at VADEQ station 1ANOR009.87 and USGS Station 01659000, which are collocated. The maximum assessment criterion is shown as a thick red line (235 *E. coli*/100 ml of water). Plotting *E. coli* data along with available stream flow data (**Figure 1-5**) revealed that the exceedances occurred in moist, mid-range flow, dry and low-flow conditions.

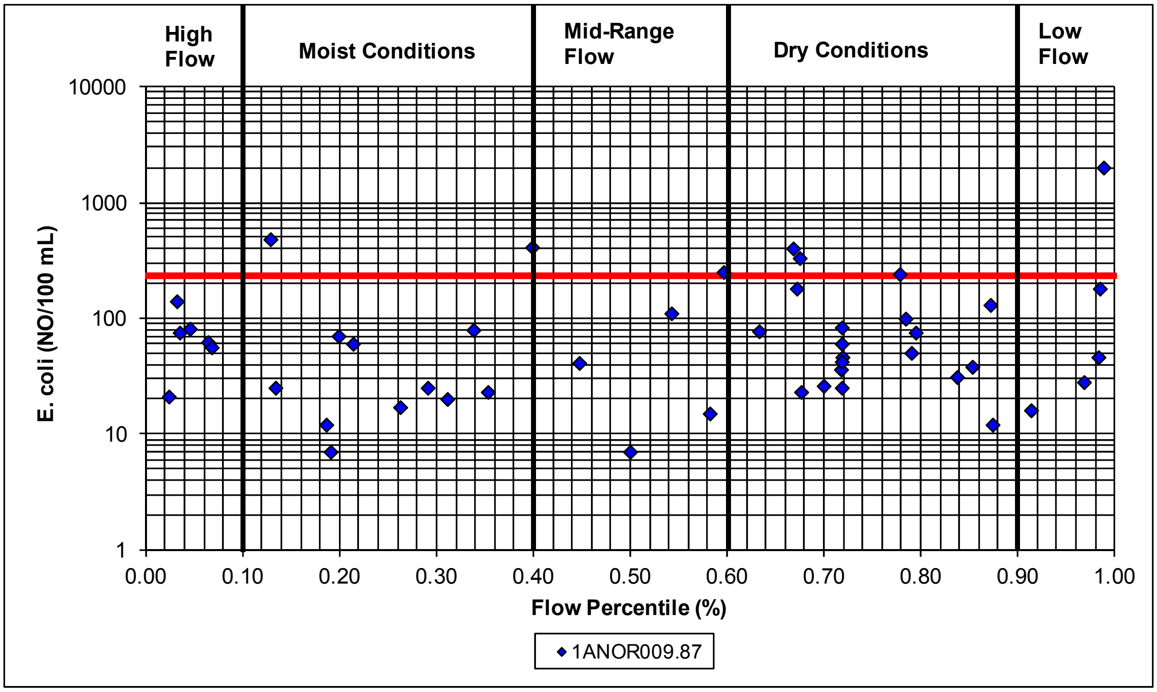

Figure 1- 5: Flow Percentile and *E. coli* Concentrations for North Branch Chopawamsic Creek at 1ANOR009.87 and USGS Station 01659000 (2007 - 2010)

With exceedances occurring in moist, mid-range, dry and low flow conditions, both higher and lower flow periods were considered as the critical conditions. Exceedances under high-flow conditions would occur from runoff based, indirect sources of bacteria, and would most likely exceed the maximum assessment criterion. Bacteria loads under low-flow conditions would likely occur from direct deposition sources of bacteria, and would most likely exceed both bacteria criteria.

The TMDL is required to meet both the geometric mean and the maximum assessment bacteria criteria. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both bacteria criteria.

1.4.2.4 Unnamed Tributary to the Potomac River

The dominant land uses in the Unnamed Tributary to the Potomac River watershed are forest (77%) and developed (9%). Potential key sources of *E. coli* include run-off from point source dischargers, residential waste, agricultural and wildlife sources.

E. coli loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available instream water quality data and flow data obtained from the nearby USGS flow monitoring station located on Aquia Creek.

The following figure shows the observed level of *E. coli* under different flow conditions at VADEQ water quality station 1AXLF000.13 (**Figure 1-6**). The data for flow was obtained from USGS station 01660400, located on Aquia Creek near Garrisonville, VA. **Figure 1-6** depicts *E. coli* concentrations recorded in 2007-2008 with the available corresponding stream flow percentile.

E. coli data were available at VADEQ listing station 1AXLF000.13. The maximum assessment criterion is shown as a thick red line (235 *E. coli*/100 ml of water). Plotting *E. coli* data along with available stream flow data (**Figure 1-6**) revealed that the exceedances occurred in dry to low-flow conditions.

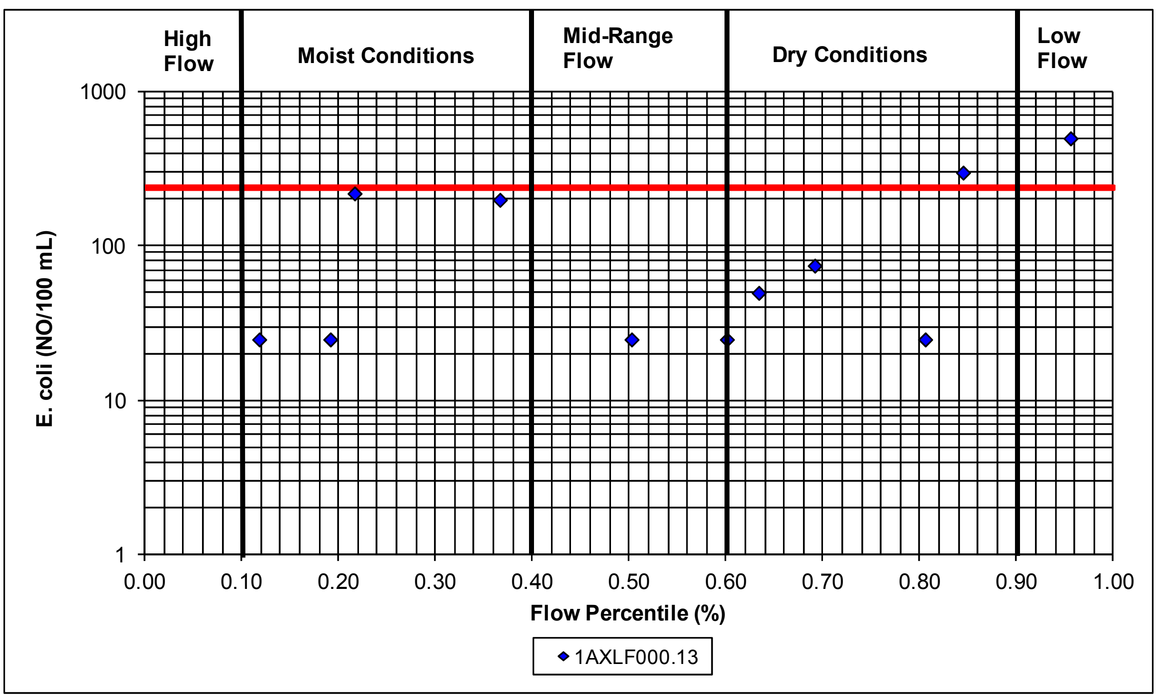

Figure 1- 6: Flow Percentile and *E. coli* Concentrations for the Unnamed Tributary to the Potomac River at 1AXLF000.13 (2007-2008)

The majority of exceedances occurred in dry or low flow conditions. Exceedances under high-flow conditions would occur from runoff based, indirect sources of bacteria. Bacteria loads under low-flow conditions would likely occur from direct deposition sources of bacteria, and would most likely exceed the maximum assessment and geometric mean criteria.

The TMDL is required to meet both the geometric mean and maximum assessment bacteria criteria. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both bacteria criteria.

1.4.2.5 Austin Run

The dominant land uses in the Austin Run watershed are developed (45%) and forest (38%). Potential key sources of *E. coli* include run-off from point source dischargers, residential waste, and agricultural and wildlife sources.

E. coli loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available instream water quality data and flow data obtained from the nearby USGS flow monitoring station located on Aquia Creek.

The following figure shows the observed level of *E. coli* under different flow conditions at VADEQ water quality station 1AAUS000.49 (**Figure 1-7**). The data for flow was obtained from USGS station USGS station 01660400, located on Aquia Creek near Garrisonville, VA. **Figure 1-7** depicts *E. coli* concentrations recorded in 2010 with the available corresponding stream flow percentile.

E. coli data were available at VADEQ listing station 1AAUS000.49. The maximum assessment criterion is shown as a thick red line (235 *E. coli*/100 ml of water). Plotting *E. coli* data along with available stream flow data (**Figure 1-7**) revealed that the exceedances occurred in high flow conditions.

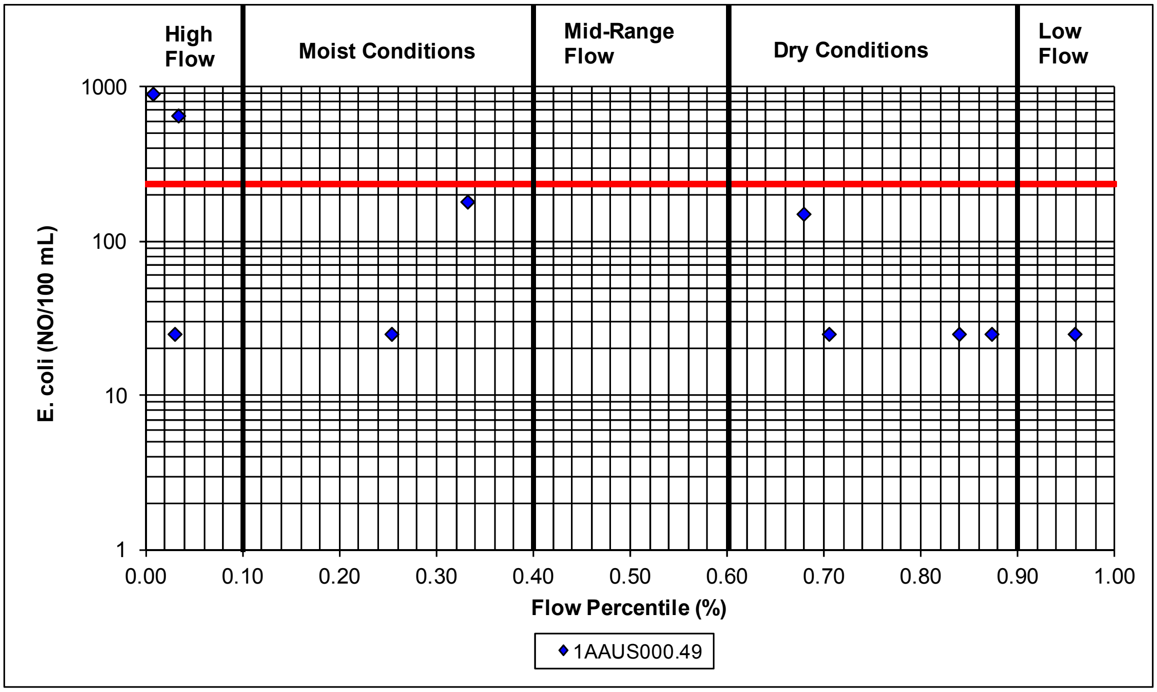

Figure 1- 7: Flow Percentile and *E. coli* Concentrations for Austin Run at 1AAUS000.49 (2010)

Exceedances under high-flow conditions would most likely occur from runoff based, indirect sources of bacteria, and would most likely exceed the maximum assessment criterion. Bacteria loads under low-flow conditions would likely occur from direct deposition sources of bacteria, and would most likely exceed both criteria.

The TMDL is required to meet both the geometric mean and maximum assessment bacteria criteria. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both criteria.

1.4.2.6 Accokeek Creek

The dominant land uses in the Accokeek Creek watershed are forest (63%) and developed (13%). Potential key sources of *E. coli* include run-off from point source dischargers, residential waste, and agricultural and wildlife sources.

E. coli loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available instream water quality data and flow data obtained from the nearby USGS flow monitoring station located on Aquia Creek.

The following figure shows the observed level of *E. coli* under different flow conditions at VADEQ water quality station 1AACC006.13 (**Figure 1-8**). The data for flow was obtained from USGS station 01660400, located on Aquia Creek near Garrisonville, VA. **Figure 1-8** depicts *E. coli* concentrations recorded between 2003 and 2010 with the available corresponding stream flow percentile.

E. coli data were available at VADEQ listing station 1AACC006.13. The maximum assessment criterion is shown as a thick red line (235 *E. coli*/100 ml of water). Plotting *E. coli* data along with available stream flow data (**Figure 1-8**) revealed that the exceedances occurred in high flow, moist, and low-flow conditions.

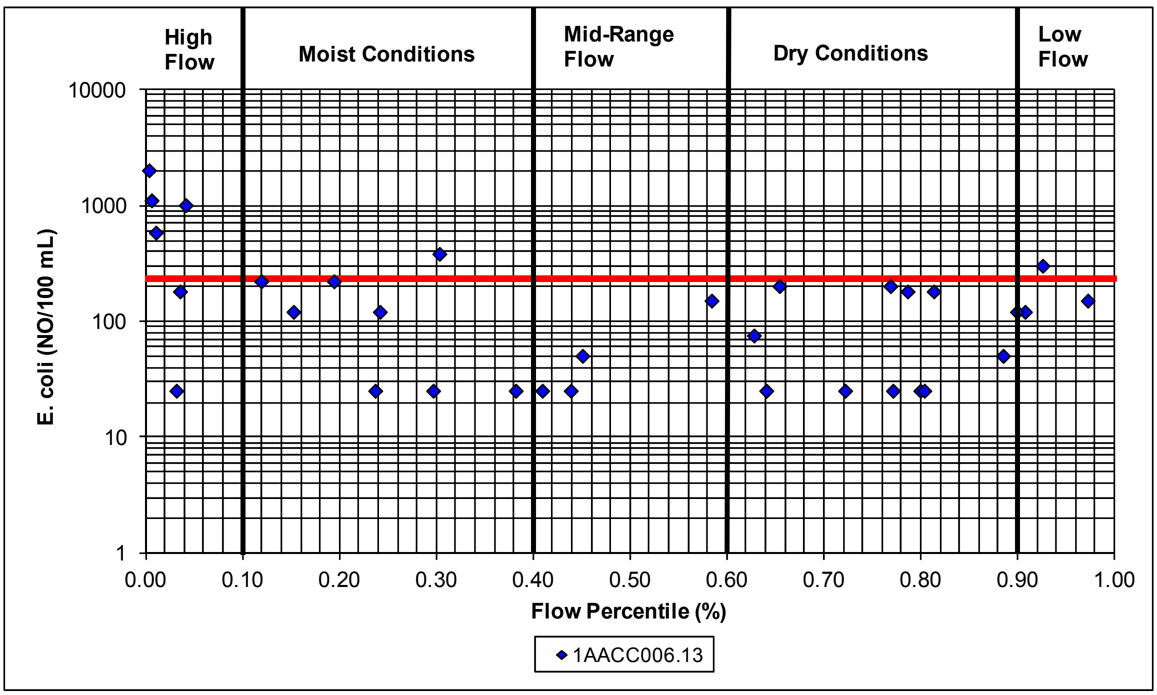

Figure 1- 8: Flow Percentile and *E. coli* Concentrations for Accokeek Creek at 1AACC006.13 (2003-2010)

With exceedances occurring in high-flow, moist and low-flow conditions, both higher and lower flow periods were considered as the critical conditions. Exceedances under high-flow conditions would most likely occur from runoff based, indirect sources of bacteria, and would most likely exceed the maximum assessment criterion. Bacteria loads under low-flow conditions would likely occur from direct deposition sources of bacteria, and would most likely exceed both criteria.

The TMDL is required to meet both the geometric mean and the maximum assessment bacteria criteria. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both criteria.

1.4.2.7 Potomac Creek and Potomac Run

The dominant land uses in the Potomac Creek and Potomac Run watershed are forest (58%) and agriculture (18%). Potential key sources of *E. coli* include run-off from residential waste and agricultural and wildlife sources.

E. coli loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available instream water quality data and flow data obtained from the nearby USGS flow monitoring station located on Aquia Creek.

The following figures show the observed levels of *E. coli* under different flow conditions at VADEQ water quality stations 1APOR000.40 (Potomac Run, **Figure 1-9**) and 1APOM006.72 (Potomac Creek, **Figure 1-10**). The data for flow was obtained from USGS station 01660400, located on Aquia Creek near Garrisonville, VA. **Figure 1-9** and **1-10** depicts *E. coli* concentrations recorded between 2003 and 2010 with the available corresponding stream flow percentile.

E. coli data were available at VADEQ listing stations 1APOR000.40 and 1APOM006.72. The maximum assessment criterion is shown as a thick red line (235 *E. coli*/100 ml of water). Plotting *E. coli* data along with available stream flow data revealed that the exceedances occurred during all flow conditions for Potomac Run (**Figure 1-9**) and during all flow conditions except low flow for Potomac Creek (**Figure 1-10**).

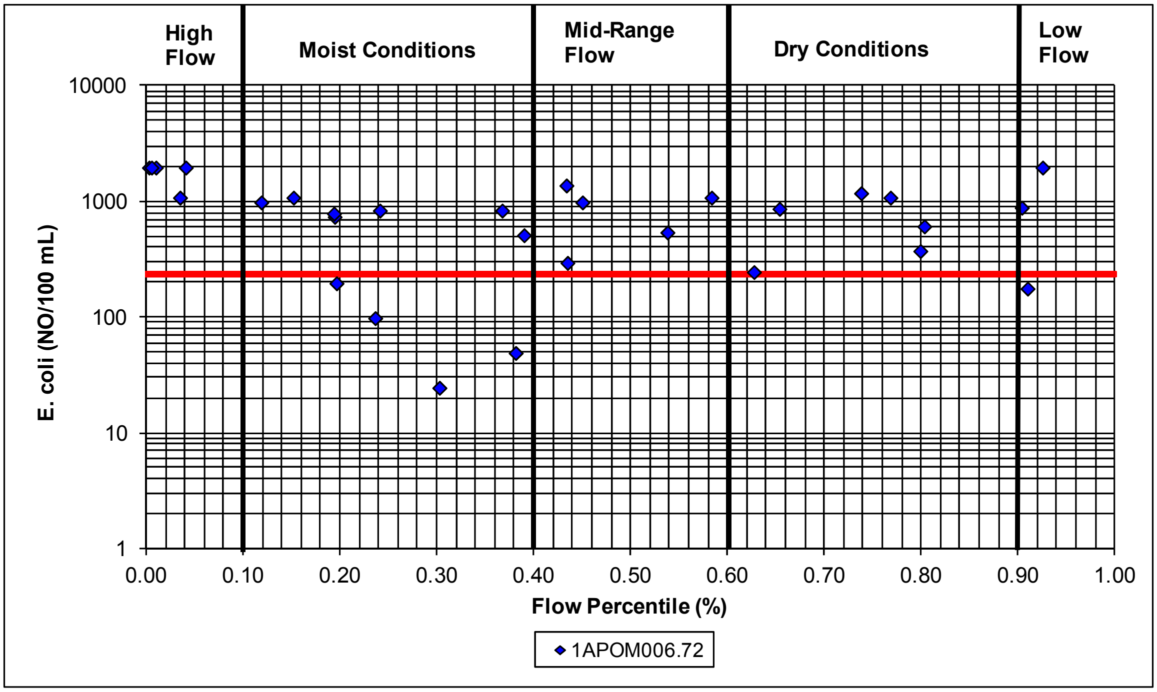

Figure 1- 9: Flow Percentile and *E. coli* Concentrations for Potomac Run at 1APOR000.40 (2003-2010)

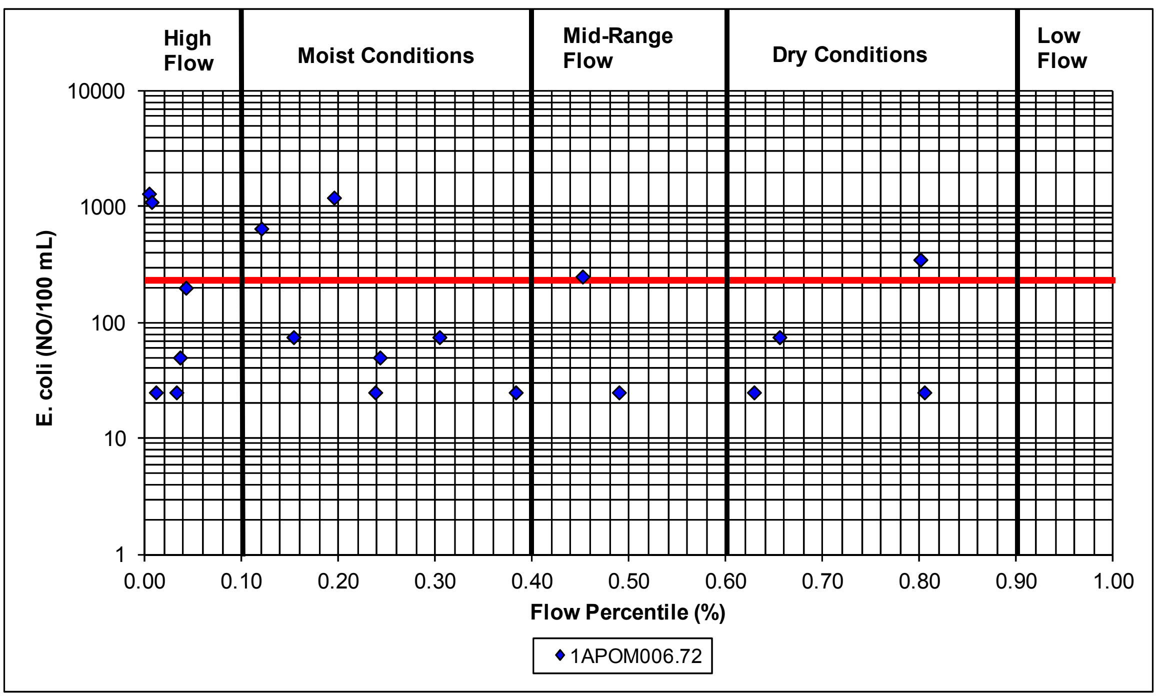

Figure 1- 10: Flow Percentile and *E. coli* Concentrations for Potomac Creek at 1APOM006.72 (2003-2010)

Since exceedances occur in all flow conditions (Potomac Run) and in all flow conditions except low flow (Potomac Creek), both higher and lower flow periods were considered as the critical conditions for both impaired segments. Exceedances under high-flow conditions would most likely occur from runoff based, indirect sources of bacteria and would most likely exceed the maximum assessment criterion. Bacteria loads under low-flow conditions would likely occur from direct deposition sources of bacteria, and would most likely exceed the maximum assessment and geometric mean criteria.

The TMDL is required to meet both the geometric mean and the maximum assessment bacteria criteria. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both bacteria criteria.

1.5 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff, and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed for the consideration of temporal variability in fecal coliform loading within the watershed.

2.0 Watershed Description and Source Assessment

In this section, the types of data available and information collected for the development of TMDLs for the bacteria impaired segments of Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run are presented. This information was used to characterize the waterbodies and their watersheds and to inventory and identify potential point and non-point sources of bacteria in the watershed.

2.1 Data and Information Inventory

A wide range of data and information were used in the development of these TMDLs. Categories of data that were used include the following:

(1) Physiographic data that describe physical conditions (i.e., topography, soils, and land use) within the watershed.

(2) Hydrographic data that describe the stream networks and reaches.

(3) Data related to uses of the watershed and other activities in the basin that can be used in the identification of potential bacteria sources.

Table 2-1 shows the various data types and the data sources used for TMDL development.

Table 2- 1: Inventory of Data and Information Used in TMDL Development

Data Category	Description	Source(s)
Watershed physiographic data	Watershed boundary	USGS HUC Boundaries
	Land use/land cover	NLCD
	Soil data (*Soil Data Mart*)	USDA-NRCS
	Topographic data (USGS-30 meter DEM)	USDA-NRCS
Hydrographic data	Stream network and reaches (1:24k resolution)	NHD
Weather data	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	NCDC
Watershed activities/ uses data and information related to bacteria production	Livestock inventory	Census of Agriculture 2007, Prince William County Soil and Water Conservation District, Stafford County, VA DCR
	Wildlife inventory	VA DGIF
	Septic systems inventory and failure rates	VA DEQ, Census Bureau, Stafford County, VDH
	Pet estimates	AVMA
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMRs)	VA DEQ
	MS4 permits	VA DCR
	SSO data and locations	VA DEQ
Environmental monitoring data	Monitoring data (bacteria water quality) and station locations	VA DEQ
	Stream flow data	USGS

Notes:
AVMA: American Veterinary Medical Association
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Cover Database
NOAA: National Oceanic and Atmospheric Association
NRCS: Natural Resources Conservation Service
USDA: United States Department of Agriculture
USGS: United States Geological Survey
VA DCR: Virginia Department of Conservation and Recreation
VA DEQ: Virginia Department of Environmental Quality
VA DGIF: Virginia Department of Game and Inland Fisheries
VDH: Virginia Department of Health

The following agencies were specifically contacted to obtain estimates for wildlife, livestock and septic systems/straight pipes:

- Tri County Soil and Water Conservation District
- Prince William County Soil and Water Conservation District
- Virginia Cooperative Extension Office – Prince William County
- Virginia Cooperative Extension Office – Fauquier
- Virginia Cooperative Extension Office – Stafford
- Prince William County Health Department

- Rappahannock Area Health District
- Virginia Department of Game and Inland Fisheries

2.2 Watershed Descriptions and Identification

The impaired streams included in this TMDL include: Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek, and Potomac Run. The watersheds of these streams occupy a combined drainage area of 137 square miles.

2.2.1 Location

The impaired watersheds addressed in this TMDL are located in the northern region of Virginia within the borders of Prince William and Stafford Counties. Additionally, all are located in Lower Potomac USGS Cataloging Unit 02070011. Watershed drainage areas and major roads within each watershed are described below.

2.2.1.1 Powells Creek

The Powells Creek watershed is located in Prince William County and occupies a drainage area of 15.2 square miles. As shown in **Figure 2-1**, the major roadways in the watershed are Interstate 95 and U.S. Highway 1, which run north-south across the eastern half of the watershed.

2.2.1.2 Quantico Creek and South Fork Quantico Creek

The Quantico Creek/South Fork Quantico Creek watershed is located in Prince William County and occupies a drainage area of 27.1 square miles. As shown in **Figure 2-1**, the major roadways in the watershed are Interstate 95 and U.S. Highway 1, which run north-south across the eastern edge; and State Highway 234, which runs east-west along the northern border between this watershed and the Powells Creek watershed. Portions of the Quantico Creek and South Fork Quantico Creek watersheds run through the Prince William Forest Park.

2.2.1.3 North Branch Chopawamsic Creek

The North Branch Chopawamsic Creek watershed occupies a drainage area of 11 square miles, 3.9 square miles of which are in Prince William County, and the remaining 7.1 square miles are in Stafford County. There are no major roadways running through the watershed. Much of this watershed is occupied by the United States Marine Corps Base – Quantico.

2.2.1.4 Unnamed Tributary to Potomac River

The Unnamed Tributary to the Potomac River (Stream Code XLF) watershed is located in Stafford County and occupies a drainage area of 4.2 square miles. There are no major roadways in the watershed.

2.2.1.5 Austin Run

The Austin Run watershed is located in Stafford County and occupies a drainage area of 11 square miles. As shown in **Figure 2-1**, the major roadways present are Interstate 95 and U.S. Highway 1, which run north-south across the eastern portion of the watershed; and State Highway 610, which runs east-west across the northern tip of the watershed.

2.2.1.6 Accokeek Creek

Accokeek Creek is located in Stafford County and occupies a drainage area of 17.5 square miles. As shown in **Figure 2-1**, the major roadways in the watershed are Interstate 95 and U.S. Highway 1, which run north-south across the center of the watershed.

2.2.1.7 Potomac Creek and Potomac Run

The Potomac Creek/Potomac Run watershed is located in Stafford County and occupies a drainage area of 50.7 square miles. As shown in **Figure 2-1**, the major roadways in the watershed are Interstate 95 and U.S. Highway 1, which run north-south across the eastern portion of the watershed; and State Highway 616, which runs north-south across the western portion of the watershed.

Figure 2- 1: Overview Map of Watersheds Included in TMDL Study

2.2.2 Topography

A digital elevation model (DEM) based on the USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from the Geospatial Data Gateway system maintained by the USDA Natural Resources Conservation Service. Elevation within the impaired watersheds ranges from 0 to 463 feet above mean sea level.

2.2.3 Hydrologic Soil Groups and Soil Types

The following section details hydrologic soil groups for the Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek, and Potomac Run TMDL watersheds. The soil hydrologic group characterization is based on data obtained from the Soil Survey Geographic (SSURGO) Database via *Soil Data Mart*, a USGS-approved program and multi-purpose environmental analysis system integrating GIS, national watershed data, and environmental assessment and modeling tools.

The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group “A” designates soils that are well- to excessively well-drained, whereas hydrologic soil group “D” designates soils that are poorly drained. This means that soils in hydrologic group “A” allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group “A,” soils in hydrologic group “D” allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 2-2**. Distribution of hydrologic groups within the TMDL watersheds is presented in **Table 2-3**. The term “blank” in the hydrologic group breakdown refers to those classes defined as water, urban land, stony steep land, stony rolling land, sand and gravel pits, dams, and cut-and-fill lands.

In addition to hydrologic soil groups, SSUGRO data obtained via Soil Data Mart was also used for watershed soil characterization. There are 90 general soil associations located in the watersheds, as presented in **Appendix A**. The dominant soil types in these watersheds are Nason, Caroline, Appling, Sassafras, and Elioak. The distribution of soils in the Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek, and Potomac Run watersheds is presented in **Appendix A**.

Table 2- 2: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well-drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well- and well-drained soils with moderately coarse textures.
B/D	Combination of Hydrologic Soils Groups B and D, where drained areas are of Soil Group B and undrained areas are of Group D.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
C/D	Combination of Hydrologic Soil Groups C and D, where drained areas are of Soil Group C and undrained areas are of Group D.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover.

2.2.3.1 Powells Creek

The major hydrologic soil groups within the Powells Creek watershed are Group B (63%) and Group C (26%) (**Table 2-3**). The major soil series are Gaila (11%), which is deep, well drained, and found on nearly level to steep uplands; and Glenelg (10%), which is very deep, well drained and found in uplands (NRCS).

2.2.3.2 Quantico Creek and South Fork Quantico Creek

The major hydrologic soil groups within the Quantico Creek/South Fork Quantico Creek watershed are Group B (63%) and Group C (26%) (**Table 2-3**). The major soil series are Buckhall (17%), which is deep, well-drained, moderately permeable and found on ridge tops and side slopes; and Fairfax (10%), which is deep, well-drained, moderately permeable and found on level to moderately sloping uplands (NRCS).

2.2.3.3 North Branch Chopawamsic Creek

The major hydrologic soil groups within the North Branch Chopawamsic Creek watershed are Group C (55%) and Group B (30%) (Table 2-3). The major soil series are Nason (30%), which is deep, well-drained, moderately permeable and found on uplands; and Fairfax (9%), which is deep, well-drained, moderately permeable and found on level to moderately sloping uplands (NRCS).

2.2.3.4 Unnamed Tributary to Potomac River

The major hydrologic soil groups within the Unnamed Tributary to Potomac River watershed are Group B (51%) and Group C (31%) (**Table 2-3**). The major soil series are Sassafras (45%), which is very deep, well-drained, has moderate or moderately slow permeability and is found on summits and side slopes; and Caroline (10%), which is deep, well-drained, has moderately slow or slow permeability and is found in marine and fluvial areas (NRCS).

2.2.3.5 Austin Run

The major hydrologic soil groups within the Austin Run watershed are Group C (38%) and Group B (35%) (**Table 2-3**). The major soil series are Appling (10%), which is deep, well-drained and moderately permeable, and found on ridges and side slopes; and Nason (10%), which is deep, well-drained, moderately permeable and found on uplands (NRCS).

2.2.3.6 Accokeek Creek

The major hydrologic soil groups within the Accokeek Creek watershed are Group C (42%) and Group B (33%) (**Table 2-3**). The major soil series are Caroline (26%), which is deep, well-drained, has moderately slow or slow permeability and is found in marine and fluvial areas; and Sassafras (14%), which is very deep, well-drained, has moderate or moderately slow permeability and is found on summits and side slopes (NRCS).

2.2.3.7 Potomac Creek and Potomac Run

The major hydrologic soil groups within the Potomac Creek/Potomac Run watershed are Group C (49%) and Group B (28%) (**Table 2-3**). The major soil series are Cullen (14%), which is very deep, well drained, moderately permeable and found on upland ridge tops and side slopes (NRCS); and Caroline (10%), which is deep, well-drained, has moderately slow or slow permeability and is found in marine and fluvial areas.

Table 2- 3: Distribution of Hydrologic Soil Groups within TMDL Watersheds

Soil Hydrologic Group	Powells Creek	%	Quantico Creek and South Fork Quantico Creek	%	North Branch Chopawamsic Creek	%	Unnamed Tributary to Potomac River	%	Austin Run	%	Accokeek Creek	%	Potomac Creek and Potomac Run	%	Total acres	Total %
A	-	-	-	-	-	-	137	5%	22	<1%	204	2%	155	<1%	561	<1%
B	6,079	63%	10,911	63%	2,098	30%	1,368	51%	2,444	35%	3,651	33%	9,223	28%	52,982	40%
B/D	-	-	-	-	-	-	55	2%	261	4%	422	4%	562	2%	2,514	2%
C	2,488	26%	4,515	26%	3,896	55%	826	31%	2,647	38%	4,652	42%	15,909	49%	51,783	39%
C/D	-	-	143	1%	117	2%	111	4%	261	4%	776	7%	1,636	5%	5,299	4%
D	953	10%	1,356	8%	912	13%	203	7%	758	11%	1,198	11%	3,981	12%	14,370	11%
[blank]	206	<1%	390	2%	-	-	8	<1%	616	9%	265	2%	951	3%	4,813	4%
TOTAL	9,725	100%	17,315	100%	7,023	100%	2,708	100%	7,010	100%	11,168	100%	32,417	100%	132,323	100%

2.2.4 Land Use

The land use characterization for the Potomac watersheds addressed in these TMDLs was based on the latest available land cover data from the National Land Cover Dataset, also known as NLCD 2006 Land Use Dataset. The distribution of land uses in the watershed, by land area and percentage, are presented in **Table 2-4**. Descriptions of the land use categories are presented in **Table 2-5**. Dominant land uses in the watersheds are Forest (64%) and Developed (12%). **Figure 2-2** depicts the land use distribution within the TMDL watersheds.

Table 2- 4: Land Use in the TMDL Watersheds

General Land Use Category	Specific LU Type	Powells Creek				Quantico Creek/South Fork Quantico Creek				North Branch Chopawamsic Creek				Unnamed Tributary to Potomac River				Austin Run				Accokeek Creek				Potomac Creek/Potomac Run							
		Acres*		% of Watershed		Acres*		% of Watershed		Acres*		% of Watershed		Acres*		% of Watershed		Acres*		% of Watershed		Acres*		% of Watershed		Acres*		% of Watershed		Total Acres		Total % of Watershed	
Developed	Developed High Intensity	192	3,063	2%	31%	107	1,166	1%	7%	-	8	-	<1%	0	250	<1%	9%	181	3,126	3%	45%	65	1,475	1%	13%	204	2,116	1%	7%	925	16,465	1%	12%
	Developed Medium Intensity	516		5%		220		1%		2		<1%		10		<1%		553		8%		158		1%		212		1%		2,202		2%	
	Developed Low Intensity	1,534		16%		510		3%		4		<1%		117		4%		1,616		23%		568		5%		563		2%		7,237		5%	
	Developed Open Space	821		8%		329		2%		2		<1%		122		5%		776		11%		684		6%		1,137		4%		6,102		5%	
Agricultural	Cultivated Crops	357	445	4%	5%	77	92	<1%	1%	52	61	<1%	1%	43	68	2%	3%	185	253	3%	4%	612	895	5%	8%	3,208	5,896	<1%	18%	5,738	9,953	4%	8%
	Pasture/Hay	88		1%		15		<1%		9		<1%		25		1%		68		1%		283		3%		2,688		8%		4,215		3%	
Forest	Deciduous Forest	4,179	4,559	43%	47%	10,841	14,722	63%	85%	2,594	5,897	37%	84%	1,895	2,086	<1%	77%	2,367	2,681	34%	38%	6,132	7,056	55%	63%	16,306	18,842	<1%	58%	68,207	85,032	52%	64%
	Evergreen Forest	194		2%		1,421		8%		1,435		<1%		82		3%		177		3%		516		5%		1,620		5%		8,943		7%	
	Mixed Forest	187		2%		2,461		14%		1,867		27%		109		4%		137		2%		408		4%		916		3%		7,882		6%	
Wetland	Palustrine Aquatic Bed	-	543	-	6%	-	852	-	5%	-	851	-	12%		163		6%	-	302	-	4%	-	881	-	8%	-	2,378	-	7%	<1	9,419	<1%	7%
	Palustrine Emergent Wetland	10		<1%		13		<1%		3		<1%		1		<1%		33		<1%		6		<1%		136		<1%		388		<1%	
	Palustrine Forested Wetland	491		5%		794		5%		782		11%		147		5%		233		3%		843		8%		2,038		6%		8,174		6%	
	Palustrine Scrub/Shrub Wetland	36		<1%		46		<1%		66		<1%		12		<1%		31		<1%		32		<1%		184		1%		618		<1%	
	Estuarine Emergent Wetland	5		<1%		0		<1%		-		-		3		<1%		5		<1%		<1		<1%		20		<1%		237		<1%	
	Estuarine Forested Wetland	-		-		-		-		-		-		-		-		-		-		-		-		-		-		<1		<1%	
	Estuarine Scrub/Shrub Wetland	-		-		-		-		-		-		-		-		-		-		-		-		-		-		1		<1%	
Water	Open Water	87	87	1%	1%	7	7	<1%	<1%	2	2	<1%	<1%	-	-	-	-	12	12	<1%	0%	21	21	<1%	<1%	260	260	1%	1%	1,645	1,645	1%	1%
Other	Scrub/Shrub	286	1,029	3%	11%	268	476	2%	3%	143	204	2%	3%	105	141	4%	5%	227	636	3%	9%	523	840	5%	8%	1,895	2,925	6%	9%	5,751	9,808	4%	7%
	Grassland/Herbaceous	80		1%		139		1%		61		<1%		19		1%		93		1%		197		2%		486		2%		1,846		1%	
	Unconsolidated Shore	1		<1%		1		<1%		-		-		14		1%		2		<1%		2		<1%		14		<1%		76		<1%	
	Bare Land	661		7%		69		<1%		-		-		3		<1%		314		4%		117		1%		531		2%		2,136		2%	
Total		**9,725**		**100%**		**17,315**		**100%**		**7,023**		**100%**		**2,708**		**100%**		**7,010**		**100%**		**11,168**		**100%**		**32,417**		**100%**		**132,322**		**100%**	

*Acreages calculated in NAD 1983 UTM Zone 18N projection

Table 2-5: Descriptions of Land Use Types

Land Use Type	Description
Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers. Impervious surfaces account for 80 to 100 percent of the total cover.
Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover.
Developed, Low Intensity	Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 21 to 49 percent of total cover.
Developed Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover.
Cultivated Crops	Areas used for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.
Deciduous Forest	Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
Palustrine Aquatic Bed	Includes tidal and non-tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages.
Palustrine Emergent Wetland	Includes all tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Plants generally remain standing until the next growing season. Total vegetation cover is greater than 80 percent.
Palustrine Forested Wetland	Includes all tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.

Table 2-5: Descriptions of Land Use Types	
Palustrine Scrub/Shrub Wetland	Includes all tidal and non tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. The species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions (Cowardin et al. 1979).
Estuarine Emergent Wetland	Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens) and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Perennial plants usually dominate these wetlands.
Estuarine Forested Wetland	Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
Estuarine Scrub/Shrub Wetland	Includes all tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
Open Water	All areas of open water, generally with less than 25 percent cover of vegetation or soil.
Scrub/Shrub	Areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.
Bare Land	Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.
Grassland/Herbaceous	Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.
Unconsolidated Shore	Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class.
Source: Coastal NLCD Classification Scheme, NOAA Coastal Services Center	

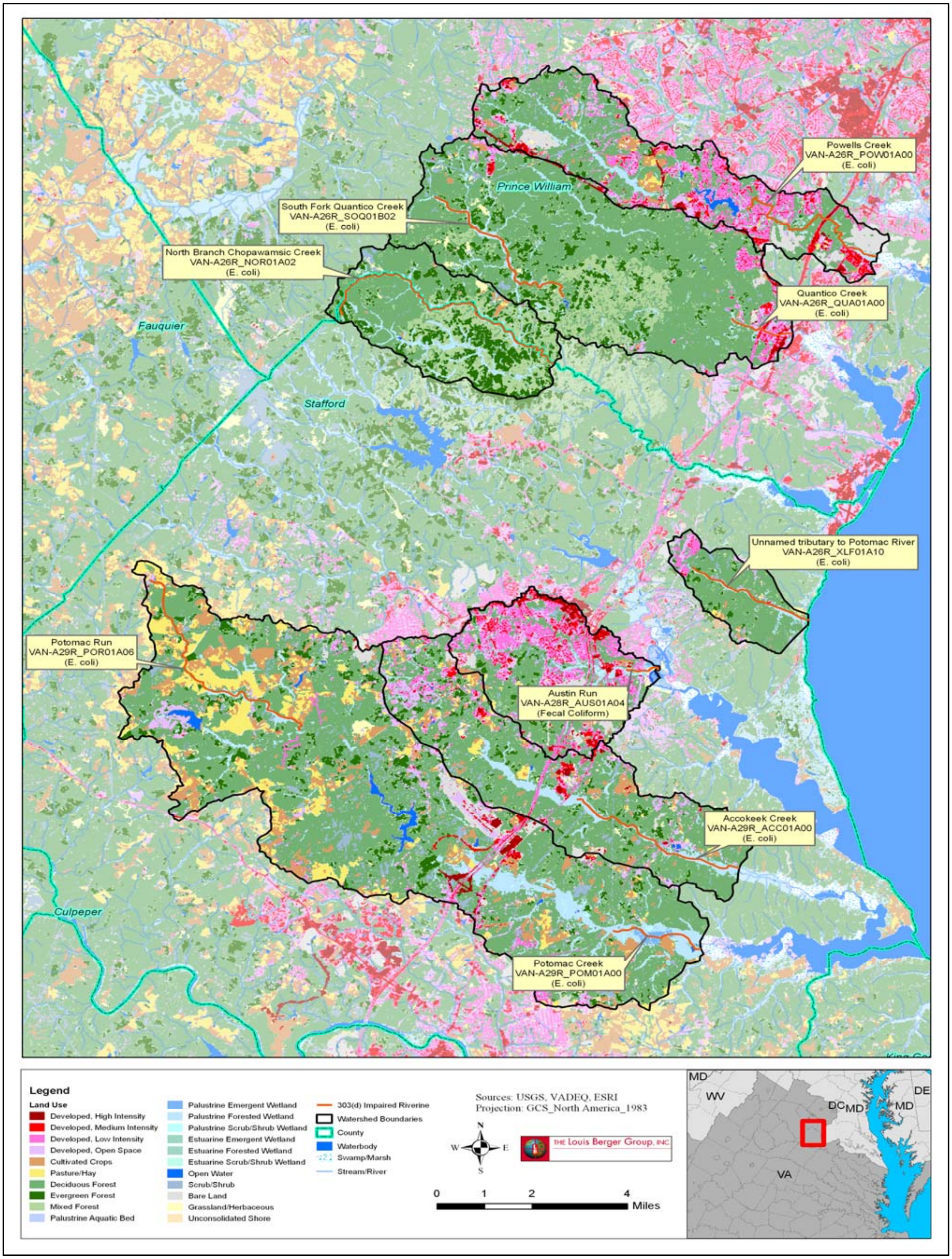

Figure 2- 2: Land Use for the TMDL watersheds

2.3 Stream Flow Data

Daily flow data were available from 10 USGS stream flow-gauging stations within the TMDL study area. Data collected at these stations are shown in **Table 2-6**. Up-to-date flow data is available from USGS station 01658500, located on the downstream end of the impaired segment of South Fork Quantico Creek; USGS stations 01659000 and 01659500, located on the downstream end of the impaired segment of North Branch Chopawamsic Creek; and USGS station 01660400, located on Aquia Creek. Locations of the USGS stations are shown in **Figure 2-3**. No historic or present USGS stream flow-gauging stations are present in the Unnamed Tributary to Potomac River, Accokeek Creek, Potomac Creek, or Potomac Run watersheds.

Table 2- 6: USGS Flow Gauges Located in the TMDL Study Area

Station	Watershed	Site Name	Period of Daily-Mean Data	
			Start Date	End Date
01657895	Powells Creek	Powells Creek near Dale City, VA	1/10/1995	07/9/1996
01658500	Quantico Creek/South Fork Quantico Creek	South Fork Quantico Creek Near Independent Hill, VA	5/1/1951	Present
01658480	Quantico Creek/South Fork Quantico Creek	Quantico Creek Near Dumfries, VA	5/19/1983	09/30/1985
01658550	Quantico Creek/South Fork Quantico Creek	South Fork Quantico Creek At Camp 5, Near Joplin, VA	6/27/1983	09/30/1985
01658650	Quantico Creek/South Fork Quantico Creek	South Fork Quantico Creek Near Dumfries, VA	5/18/1983	09/30/1985
01659000	North Branch Chopawamsic Creek	North Branch Chopawamsic Creek Near Independent Hill, VA	5/1/1951	Present
01659500	North Branch Chopawamsic Creek	Middle Branch Chopawamsic Creek Near Garrisonville VA	5/1/1951	Present
01660380	Austin Run	Cannon Creek Near Garrisonville, VA	11/23/1994	11/25/1996
01660400	Austin Run	Aquia Creek Near Garrisonville, VA	9/1/1971	Present
01660500	Austin Run	Beaverdam Run Near Garrisonville, VA	5/1/1951	12/31/2003

2.4 Ambient Water Quality Data for Bacteria

Environmental monitoring efforts for collecting bacteria data in the TMDL watersheds have been conducted by the Virginia Department of Environmental Quality (VA DEQ) and U.S. Geological Survey (USGS). All available bacteria data for streams located within the TMDL watersheds were analyzed and compared to VA DEQ water quality criteria for bacteria. Data extend through the end of 2010. **Table 2-7** summarizes VA DEQ monitoring efforts for all bacteria indicators according to Station ID.

Table 2- 7: Summary of Instream Monitoring for Bacteria

Station ID	Stream	Indicator	Number of Samples	Sample Date		Minimum[1,2]	Maximum[1,2]
				First	Last		
Powells Creek							
1APOW003.11	Powells Creek	Fecal Coliform	11	12/16/1998	11/30/2006	25	700
		E. coli	13	2/6/2003	10/19/2010	25	420
1APOW006.11	Powells Creek	Fecal Coliform	2	10/5/2006	11/30/2006	25	50
		E. coli	23	8/7/2003	10/19/2010	25	2000
1APOW009.99	Powells Creek	Fecal Coliform	0	-	-	-	-
		E. coli	9	8/7/2003	6/14/2005	25	950
Quantico Creek/South Fork Quantico Creek							
1AQUA004.46	Quantico Creek	Fecal Coliform	60	11/17/1998	10/12/2010	25	2000
		E. coli	47	7/16/2003	10/12/2010	25	2000
1ASOQ003.17	South Fork Quantico Creek	Fecal Coliform	-				
		E. coli	13	11/20/2003	6/20/2005	25	330
1ASOQ006.73/ USGS 01658500	South Fork Quantico Creek	Fecal Coliform	-	-	-	-	-
		E. coli	75	1/14/2003	12/14/2010	3	1500
North Branch Chopawamsic Creek							
1AMIP000.40	Middle Branch Chopawamsic Creek	Fecal Coliform	-	-	-	-	-
		E. coli	9	2/25/2010	10/18/2010	25	220
1ANOR009.87/ USGS01659000	North Branch Chopawamsic Creek	Fecal Coliform	-	-	-	-	-
		E. coli	48	2/22/2007	12/14/2010	7	2000
Unnamed Tributary to Potomac River							
1AXLF000.13	Unnamed Tributary to Potomac River	Fecal Coliform	-	-	-	-	-
		E. coli	11	3/12/2007	11/29/2007	25	500
Austin Run							
1AAUS000.49	Austin Run	Fecal Coliform	8	9/12/2001	6/10/2003	100	1200
		E. coli	10	1/25/2010	10/19/2010	25	900
Accokeek Creek							
1AACC006.13	Accokeek Creek	Fecal Coliform	10	12/16/1998	6/10/2003	100	1700
		E. coli	33	7/15/2003	10/19/2010	25	2000
Potomac Creek/Potomac Run							
1APOM006.72	Potomac Creek	Fecal Coliform	10	12/16/1998	6/10/2003	100	1300
		E. coli	19	7/15/2003	10/19/2010	25	1300

Table 2- 7: Summary of Instream Monitoring for Bacteria

Station ID	Stream	Indicator	Number of Samples	Sample Date		Minimum[1,2]	Maximum[1,2]
				First	Last		
1APOM012.24	Potomac Creek	Fecal Coliform	-	-	-	-	-
		E. coli	19	9/23/2003	10/19/2010	25	950
1APOM013.02	Potomac Creek	Fecal Coliform	3	4/29/2003	6/25/2003	25	25
		E. coli	21	4/29/2003	10/14/2010	10	150
1APOM013.41	Potomac Creek	Fecal Coliform	-	-	-	-	-
		E. coli	4	7/28/2003	10/15/2003	25	25
1ALOH002.20	Able Lake	Fecal Coliform	-	-	-	-	-
		E. coli	4	7/8/2003	10/15/2003	25	25
1ALOH007.93	Long Branch	Fecal Coliform	17	4/20/1999	9/26/2007	50	100
		E. coli	18	5/20/2004	10/18/2007	25	50
1AXLB001.49	Unnamed Tributary to Long Branch	Fecal Coliform	1	4/26/2006	-	75	75
		E. coli	1	4/26/2006	-	90	90
1APOR000.40	Potomac Run	Fecal Coliform	-	-	-	-	-
		E. coli	30	7/15/2003	10/19/2010	25	2000

[1] Units for Fecal Coliform: MPN/100 ml

[2] Units for *E. coli*: CFU/100 ml

Table 2-8 shows the total number and percentage of samples exceeding the water quality maximum assessment water quality criterion for *E. coli* of 235 cfu/ 100 ml and the historic water quality criterion of 400 MPN/ 100 ml for Fecal Coliform bacteria. **Figure 2-3** presents the locations of VA DEQ's water quality monitoring stations and USGS flow/measurement stations within the NRO Lower Potomac watersheds.

Table 2- 8: Summary of VA DEQ Bacteria Exceedances

Station ID	Stream	Cause	Exceedance Rate*
1APOW006.11	Powells Creek	*E. coli*	2/13 (15.4%)
1AQUA004.46	Quantico Creek	*E. coli*	7/27 (26%)
01658500 (USGS)	S. Fork Quantico Creek	*E. coli*	7/47 (15%)
01659000 (USGS)	North Branch Chopawamsic Creek	*E. coli*	2/7 (12%)
1AAUS000.49	Austin Run	Fecal Coliform	3/8 (37.5%)**
1AXLF000.13	Unnamed Tributary to Potomac River	*E. coli*	2/11 (18%)
1AACC006.13	Accokeek Creek	*E. coli*	4/23 (17%)
1APOM006.72	Potomac Creek	*E. coli*	4/13 (31%)
1APOR000.40	Potomac Run	*E. coli*	10/13 (77%)

*Exceedance rate listed in Virginia's 2010 305(b)/303(d) Water Quality Integrated Assessment

**Exceedance rate listed in Virginia's 2006 305(b)303(d) Water Quality Integrated Assessment

Figure 2- 3: VA DEQ Water Quality Monitoring Stations and USGS Flow Stations in the TMDL Watersheds

2.5 Bacteria Source Assessment

This section focuses on characterizing the sources that potentially contribute to the bacteria loadings in the TMDL watersheds. These sources include permitted facilities, septic systems, livestock, wildlife, and pets.

Based on data obtained from VA DEQ, there are five facilities permitted by the Virginia Pollutant Discharge Elimination System (VPDES) Program that are located within the impaired watersheds and are expected to discharge the contaminant of concern. In addition to VPDES permits, Municipal Separate Storm Sewer System (MS4) permits have been issued to cities, counties and other facilities within the TMDL watersheds. Information regarding bacteria sources has been obtained from published sources as well as citizen feedback and involvement.

2.5.1 Permitted Facilities

There are three facilities holding active individual Virginia Pollutant Discharge Elimination System (VPDES) permits, issued through the VPDES permitting program, in this TMDL watershed that are expected to discharge the contaminant of concern (bacteria). The permit number, facility name, design flow and permit concentration (cfu/ 100 ml) for each of these facilities are presented in **Table 2-9**. The available flow data and water quality for the permitted facilities was retrieved and analyzed. Average flows for the permitted facilities were used in the HSPF model set-up and calibration.

In addition, there are two facilities with general permits for Domestic Sewage Discharges of Less Than or Equal to 1,000 Gallons per Day (also known as “Single Family Home General Permits”) located in the TMDL watershed. Facilities holding this type of general permit are also expected to discharge the contaminant of concern and thus, are listed below in **Table 2-9,** along with their permit number, facility name, design flow and permit concentration (cfu/ 100 ml).

In addition to the VPDES permits presented above, there are currently 7 Municipal Separate Storm Sewer System (MS4) permits issued to cities, counties and other facilities within the TMDL watersheds. These permits are detailed in **Table 2-10**. For Phase I MS4

Permits (for example, Prince William County), all land-based loadings from urban/developed land use categories (i.e. high intensity developed and medium intensity developed land uses) within the impaired watersheds were allocated to the MS4 permits. For Phase II Permits (i.e. Stafford County, Town of Dumfries, etc.) all land-based loadings from urban/developed land use categories (i.e. high intensity developed and medium intensity developed land uses) within the United States Census-defined urban areas of the permit boundaries were allocated to the MS4s. This approach for developing MS4 allocations is a land-use based approach. One disadvantage to this approach is that it is not able to distinguish between urban areas that drain to MS4s and those that drain to pervious areas, allowing infiltration into subsurface flows, or directly to surface waters. However, at the time of TMDL development, detailed information regarding the portion of watershed that drains to a MS4 system was not available, so a conservative, land-use based approach was used. The WLAs for MS4 permittees can be revised in the future, as necessary, if additional information regarding the MS4 drainage areas becomes available.

Due to the spatial overlap between MS4 entities and the resulting uncertainty of the appropriate operator of the system, the MS4 loads are aggregated by jurisdiction (Prince William County or Stafford County) in the TMDL. In most cases, the boundaries of MS4 areas are not available in enough geospatial detail to disaggregate the MS4 loads and assign individual Waste Load Allocations. EPA, DEQ, and DCR support the aggregation of MS4 WLAs for this reason. Additionally, aggregation encourages stakeholder cooperation and speeds the implementation of appropriate BMPs to address reductions required by the TMDL.

Table 2- 9: VPDES Permitted Facilities in the TMDL Watersheds (Expected to Discharge Contaminant of Concern)

Permit Number	Permit Type	Facility Name	Watershed	Max Design Flow (MGD)	Permit Concentration (cfu/100 ml)
VA0092479	Municipal, Minor	Abrahms Ct STP*	Austin Run	0.0036	126
VA0060968	Municipal, Major	Aquia Wastewater Treatment Plant	Austin Run	12	126
VA0089630	Municipal, Minor	Randall STP	Accokeek Creek	0.0008	126
VAG406114	General Permit Domestic Sewage	Business	Unnamed Tributary to Potomac River	0.001	126
VAG406207	General Permit Domestic Sewage	Residence	Accokeek Creek	0.001	126

*This permit is still in draft form and has not been officially issued.

Table 2- 10: MS4 Permits within the TMDL Study Area

Permit Number	MS4 Permit Holder
VAR040056	Stafford County
VAR040069	United States Marine Corps, Quantico
VAR040071	Stafford County Public Schools
VAR040100	Prince William County Public Schools
VAR040115	Virginia Department of Transportation
VAR040117	Town of Dumfries
VA0088595	Prince William County*

*Phase I MS4 Permit

2.5.2 Sanitary Sewer System, Septic Tanks, and Straight Pipes

Houses can be connected to a public sanitary sewer, a septic tank, or the sewage can be disposed of by other means. Estimates of the total number of households using each type of waste disposal are presented in this section.

The 2009 U.S. Census Bureau data documents population growth rates and number of houses per county. The data for Prince William and Stafford counties were reviewed to establish total population estimates and number of houses within each watershed. The last year the Census Bureau tracked the distribution of houses on sewage systems, septic systems, and other means (considered to be straight pipes) was 1990. Thus, assuming a similar distribution in 2009, 1990 distributions were multiplied by the 2009 population and housing unit numbers to estimate the number of houses currently on public sewers, septic tanks and other means. It was assumed that only urban areas contain houses. Thus, estimated numbers for septic, sewer, and other means were prorated to the watershed area based on the ratio of urban acres within the watershed to acres of urban area within the county. A summary of the census data and population estimates used for the TMDL watershed are presented in **Table 2-11**.

In order to determine the amount of bacteria contributed by human sources, it is necessary to estimate the failure rates of septic systems and systems classified as "other means." The 1990 U.S Census Report category "other means" includes the houses that dispose of sewage in other ways than by public sanitary sewer or a private septic system. Typically, the houses included in this category are assumed to be disposing of sewage directly via straight pipes, if located within 200 feet of a stream. In the case of these impaired watersheds, stakeholders indicated that there are currently no known straight pipes within 200 ft of the stream. This was based on information from the various county health departments, who commented that immediate action is taken whenever a straight pipe is found. However, since there are potentially some unknown straight pipes within the watershed, a 3% failure rate of homes on "other means" was used for any homes on "other means" in the impaired watersheds. The percentage of failing septic system in each TMDL watershed was calculated by multiplying the number of septic systems in each watershed by an estimated 3% septic failure rate (VA DEQ, 2011). The last column in **Tables 2-11** and **2-12** show the combined number of homes with a failing sewage disposal system (includes failure rates for both homes on septic systems and homes on "other means").

Table 2-11 also shows the estimated amount of failing septic systems per county. **Table 2-12** shows the estimated amount of population, number of houses, number of houses on public sewer, number of houses on septic systems, number of houses on other means, and number of failing sewage disposal systems per TMDL watershed.

Table 2-11: Population Estimates for Prince William and Stafford Counties

County	Population [1]	Number of Houses[1]	Number of Houses Public Sewer[2]	Number of Houses on Septic Systems	Number of Houses with Failing Septic Systems[3]	Number of Houses on "Other Means"	Estimated Number of Houses with a Failing Sewage Disposal System (Failing Septic Systems and Other Means)[3]
Prince William	379,166	137,651	115,296	21,764	653	591	671
Stafford	124,166	43,585	24,855	18,044	541	686	562

[1] Census 2009 estimates

[2] Based upon 2009 census estimate and ratio of parameter: 1990 census estimate

[3] Based on a failure rate of 3% (VA DEQ 2011)

Table 2- 12: Population Estimates for the TMDL Watersheds

Watershed	Population [1]	Number of Houses[1]	Number of Houses Public Sewer[2]	Number of Houses on Septic Systems[2]	Number of Houses with Failing Septic Systems[3]	Number of Houses on "Other Means"[2]	Estimated Number of Houses with a Failing Sewage Disposal System (Failing Septic Systems and Other Means)[3]
Powells Creek	23,588	8,563	7,172	1,354	41	37	42
Quantico Creek/ South Fork Quantico Creek	2,882	3,195	2,676	505	15	14	15
North Branch Chopawamsic Creek	75	26	22	4	0	0	0
Unnamed Tributary to Potomac River	1,234	433	247	179	5	7	6
Austin Run	22,647	7,949	7,711*	238*	7	125	11
Accokeek Creek	7,636	2,680	1,528	1,110	33	42	34
Potomac Creek/ Potomac Run	9,448	3,316	1,891	1,373	41	52	43

[1] Census 2009 estimates

[2] Based upon 2009 census estimate and ratio of parameter: 1990 census estimate

[3] Based on a failure rate of 3% (VA DEQ 2011)

*Based on percentage provided by Stafford County

2.5.3 Livestock

An inventory of the livestock in the TMDL watersheds was conducted using data and information provided by the United States Department of Agriculture (USDA) Census of Agriculture (2007), and stakeholders input. Livestock information was available for all counties in the watershed. This database was used to determine the livestock inventories per county, shown in **Table 2-13**, and per TMDL watershed, shown in **Table 2-14**.

Preliminary livestock estimates for each of the impaired watersheds were obtained by:

- Collecting information regarding the total number of livestock, as well as the total number of pastureland acres, in each of the counties included in the study area. This information was obtained from the United States Department of Agriculture (USDA) 2007 Agricultural Census.
- Determining the total amount of pastureland in each impaired watershed (calculated via GIS, with 2006 NLCD land cover).
- Incorporating this information into a ratio to determine the estimated number of each type of livestock in the impaired watershed.

Example Using Hypothetical Numbers:

$$\frac{\text{Acres of Pastureland in Impaired Watershed}^{*}}{\text{Acres of Pastureland in County}^{\#}} = \frac{\text{Number of Horses in Impaired Watershed}}{\text{Number of Horses in County}^{\#}}$$

$$\frac{20 \text{ acres}}{100 \text{ acres}} = \frac{X}{50 \text{ horses}}$$

$$X = 10 \text{ horses}$$

**Obtained from NLCD Land Use GIS Layer*
 # Obtained from the 2007 Agricultural Census

Table 2- 13: Livestock Present in Prince William and Stafford Counties[1]									
TMDL Watershed	Beef Cows	Milk Cows	Other Cattle	Hogs/Pigs	Sheep and Lambs	Chickens	Chickens (Layers)	Turkeys	Horses
Prince William	1,373	840	2,026	20	594	0	687	6	1,833
Stafford	1,117	0	1,158	0	450	0	316	74	1,405

[1] Based on USDA 2007 Agricultural Census Data (http://www.agcensus.usda.gov/Publications/2007/Full_Report/index.asp)

Table 2- 14: Livestock Present in TMDL Watersheds									
Watershed	Beef Cows	Milk Cows	Other Cattle	Hogs/Pigs	Sheep and Lambs	Chickens	Chickens (Layers)	Turkeys	Horses
Powells Creek[1]	30	20	45	0	15	0	15	0	100
Quantico Creek/South Fork Quantico Creek[1]	5	0	5	0	5	0	5	0	0
North Branch Chopawamsic Creek[1]	0	0	0	0	0	0	0	0	0
Unnamed Tributary to Potomac River[2]	5	0	5	0	0	0	5	0	0
Austin Run[2]	15	0	17	0	0	0	12	0	8
Accokeek Creek[2]	50	0	50	0	20	0	15	5	65
Potomac Creek/ Potomac Run[2]	335	0	345	10	135	0	95	20	420

[1] Based on input from Prince William County SWCD and USDA 2007 Agricultural Census Data (http://www.agcensus.usda.gov/Publications/2007/Full_Report/index.asp)

[2] Based on input from Stafford County, DCR and USDA 2007 Agricultural Census Data

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. **Table 2-15** shows the average fecal coliform production per animal per day contributed by each type of livestock.

Table 2- 15: Daily Fecal Coliform Production Rates for Livestock Present in TMDL Watersheds

Livestock Type	Daily Fecal Coliform Production (cfu/day)	Reference
Other Dairy Cow (including heifers)	1.16E+10	Virginia Tech, 2000
Beef Cows	3.3E+10	Virginia Tech, 2000
Dairy Cows	2.52E+10	Virginia Tech, 2000
Hogs	1.08E+10	ASAE, 1998
Sheep	2.70E+10	Virginia Tech, 2000
Horses	4.20E+08	Virginia Tech, 2000
Chickens	1.36E+08	ASAE, 1998

The impact of fecal coliform loading from livestock is dependent upon whether loadings are directly deposited into the stream, or indirectly delivered to the stream via surface runoff. For this TMDL, fecal coliform deposited while livestock were in confinement or grazing was considered indirect deposit, and fecal coliform deposited when livestock directly defecate into the stream was considered direct deposit. The distribution of daily fecal coliform loading between direct and indirect deposits was based on livestock daily schedules.

For each of the impaired watersheds, the initial estimates of the beef cattle daily schedule were based on the Difficult Run TMDL (EPA Approved, 2008).

The daily schedule for beef cattle is presented in **Table 2-16** and the daily schedule for dairy cows is presented in **Table 2-17**. The time beef cattle and dairy cows spend in the pasture or loafing was used to determine the fecal coliform load deposited indirectly. The directly deposited fecal coliform load from livestock was based on the amount of time they spend in the stream.

Table 2- 16: Daily Schedule for Beef Cattle		
Month	Time Spent in	
	Pasture (Hour)	Stream (Hour)
January	24	0.50
February	24	0.50
March	24	0.75
April	24	1.00
May	24	1.00
June	24	1.25
July	24	1.25
August	24	1.25
September	24	1.00
October	24	0.75
November	24	0.75
December	24	0.50

Table 2- 17: Daily Schedule for Dairy Cows		
Month	Time Spent in	
	Pasture (Hour)	Stream (Hour)
January	7.70	0.25
February	7.70	0.25
March	8.60	0.50
April	10.10	0.75
May	10.80	0.75
June	11.30	1.00
July	11.80	1.00
August	11.80	1.00
September	11.80	0.75
October	11.50	0.50
November	10.80	0.50
December	9.40	0.25

2.5.4 Land Application of Manure

Land application of the manure that cattle produce while in confinement is a typical agricultural practice. Both dairy operations and beef cattle are present in some of the watersheds. The manure produced by confined livestock was directly applied on the pasturelands, and was treated as an indirect source in the development of the TMDLs.

2.5.5 Wildlife

The wildlife inventory for the TMDL watersheds was developed based on numbers used in the Difficult Run Bacteria TMDL Report (VA DEQ) and provided by the Department of Game and Inland Fisheries (DGIF). The number of wildlife in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities provided by the Difficult Run Bacteria TMDL Report (VA DEQ), DGIF and stakeholder input are presented in **Table 2-18**. Information from these databases was used to determine the wildlife inventory for each TMDL watershed as shown in **Table 2-19.**

Table 2-18: Wildlife Densities in the TMDL Watersheds[1]

Wildlife type	Land use Requirements	TMDL estimates (#/acre)
Deer	Entire watershed	0.12 animals/acre
Raccoon	Entire watershed	0.31 animals/acre
Muskrat	Within 60 feet of streams and ponds (urban, grassland, forest, wetlands)	0.23 animals/acre
Beaver	Per mile of rivers and streams	2 animals/mile
Goose-Summer	Within 300 feet of streams and ponds (urban, grassland, wetlands)	2.34 animals/acre
Goose-winter	Within 300 feet of streams and ponds (urban, grassland, wetlands)	2.50 animals/acre
Duck- Summer	Within 300 feet of streams and ponds (urban, grassland wetlands, forest)	0.06 animals/acre
Duck- Winter	Within 300 feet of streams and ponds (urban, grassland wetlands, forest)	0.37 animals/acre
Turkey	Entire watershed excluding urban land uses	0.01 animals/acre

[1] Source: Difficult Run Bacteria TMDL Report (VA DEQ), Department of Game and Inland Fisheries (DGIF)

Table 2- 19: Wildlife Present Per TMDL Watershed[1]										
TMDL Watershed	**Acres**	**Deer**	**Raccoon**	**Muskrat**	**Beaver**	**Goose-Summer**	**Goose Winter**	**Duck Summer**	**Duck Winter**	**Wild Turkey**
Powells Creek	9,725	1,169	3,019	95	72	2,068	2,209	126	779	66
Quantico Creek/South Fork Quantico Creek	17,315	2,081	5,375	209	141	1,761	1,881	258	1,593	162
North Branch Chopawamsic Creek	7,023	842	2,175	81	53	1,395	1,491	100	615	70
Unnamed Tributary to Potomac River	2,708	326	841	32	22	410	438	38	234	25
Austin Run	7,007	501	118	1	58	5,412	5,782	355	544	1
Accokeek Creek	11,168	1,340	3,461	156	110	2,475	2,644	195	1,205	97
Potomac Creek/Potomac Run	32,417	3,889	10,046	342	272	5,377	5,745	446	2,748	300
[1] Based on the Difficult Run Bacteria TMDL Report (VA DEQ), Department of Game and Inland Fisheries (DGIF)										

The fecal coliform production and percentage of the day in stream access for each wildlife animal is presented in **Table 2-20**.

Table 2-20: Daily Schedule and Fecal Coliform Production for Wildlife		
Wildlife Type	**Daily Fecal Coliform Production (cfu/day)**	**Percentage of Day Spent in Stream**
Ducks	2.43E+09	75%
Goose	7.99E+08	50%
Deer	3.47E+08	1%
Beaver	2.00E+05	90%
Raccoons	1.13E+08	10%
Wild Turkey	9.30E+07	5%
Muskrat	2.50E+07	50%
Mallard	2.43E+09	50%

2.5.6 Pets

The two types of domestic pets that were considered potential bacteria sources in this watershed were cats and dogs. As of 2007, the American Veterinary Medical Association estimates densities of 0.632 dogs per household and 0.713 cats per household. **Table 2-21** shows the number of pets per TMDL watershed based on AVMA densities.

Table 2- 21: Pet Inventory for the TMDL Watersheds[1]			
Watershed	**Households**	**Estimated Dog Population**	**Estimated Cat Population**
Powells Creek	8,563	5,400	6,100
Quantico Creek/South Fork Quantico Creek	3,195	2,020	2,280
North Branch Chopawamsic Creek	27	17	19
Unnamed Tributary to Potomac River	433	275	310
Austin Run	7,949	5,024	5,668
Accokeek Creek	2,680	1,700	1,910
Potomac Creek/Potomac Run	3,317	2,100	2,365
[1]Based on American Veterinary Medical Association Pet Densities			

2.5.7 Bacteria Source Tracking Data from Prince William County

In past bacteria TMDLs developed by VADEQ, Bacteria Source Tracking (BST) sampling was performed in order to obtain a general overview of the types of bacteria sources (wildlife, livestock, human, or pet) present in the impaired watersheds. While DEQ did not perform BST sampling on any of the streams included in this TMDL, the Prince William County Department of Public Works did collect BST samples on multiple streams throughout Prince William County, including Powells Creek and Quantico Creek, both of which are included in this TMDL Report.

The Prince William County (PWC) and Virginia Tech (VT) study spanned a seven-year period (2003-2010) that included monitoring the bacteriological quality of water (based on enumerating fecal coliforms and/or *Escherichia coli*), and performing microbial source tracking (MST) to determine the sources of fecal pollution (Hagedorn, 2011). The results of the study indicated that wildlife and pet sources were evident in both the Powells Creek and Quantico Creek watersheds. This information complements the existing loading allocation estimates for both watersheds as is shown in Chapters 3 and 4 of this report.

3.0 Modeling Approach

This section describes the modeling approach used in TMDL development. The primary focus is on the sources represented in the model, assumptions used, model set-up, model calibration and validation, and the existing load.

3.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the waterbody that can:

- represent the watershed characteristics
- represent the point and non-point sources of fecal coliform and their respective contribution
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform)
- estimate the instream pollutant concentrations and loadings under the various hydrologic conditions
- allow for direct comparisons between the instream conditions and the water quality standard

3.2 Watershed Boundaries

The bacteria impaired Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run watersheds share a hydrologic drainage area that is approximately 125,897 acres or 197 square miles. This area is larger than the combined area of the individual bacteria impaired watersheds because of the incorporation of an additional drainage area necessary for the hydrology calibration (Section 3-10) and also due the fact that the existing water quality conditions in the impaired segments are not only affected by bacteria loads draining within the impaired watershed but also from loads draining from areas upstream of the impaired segments. The hydrologic modeling area drains portions of Fauquier, Prince William, and Stafford counties. **Figure 3-1** shows both the bacteria impaired watersheds and the hydrologic modeling area.

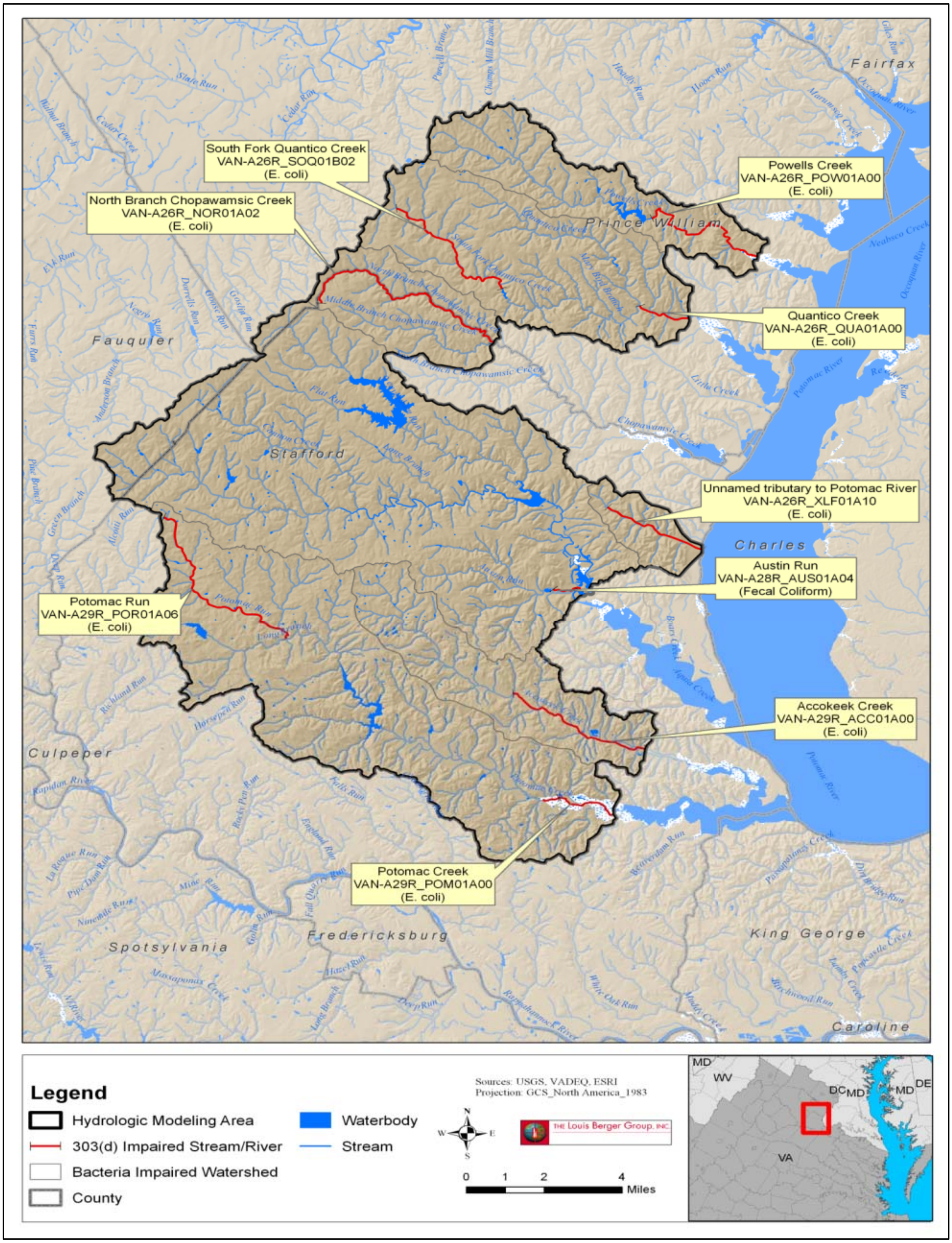

Figure 3- 1: Watershed Boundaries and Hydrologic Modeling Area

3.3 Modeling Strategy

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used to predict the instream water quality conditions under varying scenarios of rainfall and fecal coliform loading. The results from the developed model are subsequently used to develop the TMDL allocations based on the existing fecal coliform load.

HSPF is a hydrologic, watershed-based water quality model. Consequently, HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineate the watershed into smaller subwatersheds
- enter the physical data that describe each subwatershed and stream segment
- enter values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

These steps are discussed in the next sections.

3.4 Watershed Delineation

For this TMDL, the river watershed was delineated into 79 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was created using a Digital Elevation Model (DEM), stream reaches obtained from the National Hydrography Dataset (NHD), and stream flow and instream water quality data. Size distributions of the 79 subwatersheds are presented in **Table 3-1.** **Figure 3-2** shows the delineated subwatersheds for the Hydrologic Modeling Area as well as the locations of the USGS flow stations. **Figure 3-3** shows the weather stations used in modeling. The Hydrologic Modeling Area, including all 79 subwatersheds, was used in the hydrologic modeling.

Table 3- 1: TMDL Hydrologic Modeling Area Segments

Modeling Segment	Drainage Area (acres)	Modeling Segment	Drainage Area (acres)
2	1,497	65	1,439
3	1,312	66	1,701
4	2,187	67	389
5	1,294	68	1,003
6	843	69	1,103
7	1,617	70	614
8	4,441	71	773
9	701	72	281
10	2,864	74	5,183
11	4,005	75	1,500
12	1,124	76	1,194
13	859	77	1,110
14	2,467	78	926
16	1,072	79	130
19	2,062	80	1,228
20	3,006	85	1,316
22	861	86	874
23	1,766	87	790
31	2,033	88	922
32	1,680	92	1,194
33	3,866	93	1,688
34	865	94	1,676
35	1,719	95	871
38	880	96	751
39	598	97	484
43	1,729	98	905
44	231	100	1,055
46	1,495	101	2,400
47	5,521	102	1,144
53	829	103	989
54	2,005	104	843
55	721	105	730
56	1,117	106	1,209
57	132	108	2,103
58	1,471	109	555
59	1,813	116	2,307
60	2,145	117	2,175
61	4,046	118	3,906
62	2,694	119	1,995
64	2,858	**TOTAL**	**125,897**

Figure 3- 2: TMDL Hydrologic Modeling Area Segments

3.5 Land Use

The distribution of land uses in the hydrologic modeling area, by land area and percentage, are presented in Appendix D. Dominant land uses in the modeling area are Deciduous Forest (51%), Mixed Forest (6%) and Palustrine Forested Wetland (6%).

3.6 Land Use Reclassification

There are 21 land use classes present in the hydrologic modeling area. These land use types were consolidated into nine land use categories to meet modeling goals, facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 21 land use types to a representative number of categories that best describe conditions and the dominant fecal coliform source categories in the watersheds. Land use reclassification was based on similarities in hydrologic characteristics and potential fecal coliform production characteristics. The reclassified land uses are presented in **Table 3-2**.

Table 3- 2: Reclassified NLCD 2006 Landuse Distribution in Modeling Segments

Model Segment	Forest	%	Cropland	%	Pasture	%	Developed High Intensity	%	Developed Low Intensity	%	Developed, Medium Intensity	%	Water	%	Other Urban	%	total
2	922	70%	38	3%	23	2%	46	3%	60	5%	43	3%	93	7%	95	7%	1,320
3	914	70%	61	5%	21	2%	6	0%	79	6%	20	2%	85	6%	128	10%	1,313
4	1,241	57%	207	9%	74	3%	41	2%	247	11%	59	3%	176	8%	135	6%	2,180
5	1,199	93%	13	1%	11	1%	0	0%	1	0%	1	0%	68	5%	2	0%	1,295
6	621	74%	30	4%	28	3%	4	0%	29	3%	13	2%	64	8%	55	7%	844
7	1,393	86%	1	0%	24	1%	1	0%	2	0%	5	0%	192	12%	1	0%	1,618
8	4,045	91%	9	0%	6	0%	58	1%	64	1%	24	1%	188	4%	50	1%	4,444
9	596	85%	0	0%	53	8%	0	0%	1	0%	0	0%	52	7%	0	0%	701
10	2,655	93%	5	0%	16	1%	0	0%	2	0%	1	0%	178	6%	11	0%	2,866
11	3,468	87%	47	1%	67	2%	0	0%	4	0%	2	0%	419	10%	2	0%	4,009
12	807	75%	19	2%	5	0%	8	1%	131	12%	39	4%	18	2%	53	5%	1,079
13	849	99%	0	0%	0	0%	0	0%	0	0%	0	0%	11	1%	0	0%	860
14	2,358	95%	2	0%	1	0%	0	0%	18	1%	3	0%	51	2%	36	1%	2,469
16	389	37%	3	0%	8	1%	55	5%	268	25%	149	14%	50	5%	133	13%	1,054
19	1,768	86%	13	1%	11	1%	0	0%	1	0%	0	0%	266	13%	4	0%	2,064
20	2,569	85%	6	0%	4	0%	0	0%	0	0%	0	0%	430	14%	0	0%	3,009
22	725	84%	3	0%	1	0%	0	0%	0	0%	0	0%	132	15%	1	0%	861
23	1,268	73%	18	1%	32	2%	0	0%	20	1%	4	0%	374	21%	31	2%	1,747
28	1,122	54%	3	0%	20	1%	32	2%	393	19%	97	5%	40	2%	373	18%	2,079
31	1,565	77%	4	0%	57	3%	0	0%	4	0%	0	0%	390	19%	6	0%	2,027

Table 3- 2: Reclassified NLCD 2006 Landuse Distribution in Modeling Segments

Model Segment	Forest	%	Cropland	%	Pasture	%	Developed High Intensity	%	Developed Low Intensity	%	Developed, Medium Intensity	%	Water	%	Other Urban	%	total
32	1,257	75%	11	1%	18	1%	18	1%	74	4%	32	2%	156	9%	111	7%	1,677
33	3,251	84%	43	1%	211	5%	0	0%	4	0%	3	0%	342	9%	16	0%	3,869
34	790	91%	0	0%	30	3%	0	0%	1	0%	0	0%	41	5%	4	0%	866
35	1,557	90%	14	1%	36	2%	0	0%	3	0%	0	0%	105	6%	5	0%	1,720
38	608	69%	28	3%	11	1%	20	2%	76	9%	30	3%	47	5%	60	7%	879
39	555	93%	6	1%	0	0%	0	0%	2	0%	0	0%	34	6%	1	0%	598
43	1,381	80%	87	5%	17	1%	5	0%	77	4%	17	1%	106	6%	39	2%	1,730
44	168	73%	2	1%	0	0%	0	0%	1	0%	0	0%	59	25%	1	1%	231
46	1,255	84%	14	1%	19	1%	2	0%	28	2%	6	0%	128	9%	45	3%	1,496
47	4,070	74%	327	6%	484	9%	0	0%	82	1%	3	0%	298	5%	262	5%	5,525
53	458	55%	101	12%	244	29%	0	0%	1	0%	0	0%	17	2%	9	1%	830
54	1,293	64%	139	7%	214	11%	1	0%	105	5%	5	0%	81	4%	168	8%	2,007
55	573	79%	10	1%	15	2%	0	0%	56	8%	0	0%	23	3%	45	6%	722
56	819	73%	45	4%	53	5%	0	0%	49	4%	22	2%	32	3%	97	9%	1,118
57	83	63%	5	4%	4	3%	0	0%	10	7%	12	9%	17	13%	1	1%	132
58	570	39%	42	3%	80	6%	10	1%	431	30%	69	5%	17	1%	228	16%	1,447
59	1,106	70%	12	1%	97	6%	20	1%	185	12%	38	2%	14	1%	104	7%	1,576
60	1,275	61%	2	0%	31	1%	21	1%	309	15%	109	5%	157	7%	201	10%	2,104
61	1,840	47%	103	3%	50	1%	70	2%	624	16%	161	4%	765	19%	332	8%	3,947
62	2,170	81%	39	1%	42	2%	0	0%	116	4%	11	0%	166	6%	128	5%	2,672
64	1,552	54%	424	15%	764	27%	0	0%	2	0%	1	0%	91	3%	25	1%	2,859
65	307	21%	0	0%	14	1%	111	8%	548	38%	234	16%	16	1%	209	15%	1,440
66	626	38%	26	2%	32	2%	9	1%	485	30%	113	7%	49	3%	293	18%	1,632
67	120	31%	0	0%	3	1%	23	6%	123	32%	59	15%	29	7%	31	8%	388
68	616	65%	134	14%	87	9%	2	0%	34	4%	5	1%	34	4%	42	4%	954
69	516	47%	277	25%	243	22%	0	0%	0	0%	0	0%	57	5%	10	1%	1,103
70	306	50%	59	10%	157	26%	0	0%	1	0%	0	0%	76	12%	15	2%	615
71	506	65%	131	17%	94	12%	0	0%	4	0%	0	0%	31	4%	8	1%	773
72	90	32%	61	22%	111	39%	0	0%	11	4%	0	0%	9	3%	0	0%	281
74	3,322	64%	297	6%	331	6%	9	0%	376	7%	76	1%	289	6%	453	9%	5,153
75	909	61%	71	5%	179	12%	0	0%	3	0%	2	0%	147	10%	191	13%	1,500
76	883	81%	41	4%	46	4%	1	0%	45	4%	10	1%	29	3%	39	4%	1,094
77	766	73%	66	6%	148	14%	2	0%	15	1%	3	0%	19	2%	29	3%	1,047

Table 3- 2: Reclassified NLCD 2006 Landuse Distribution in Modeling Segments

Model Segment	Forest	%	Cropland	%	Pasture	%	Developed High Intensity	%	Developed Low Intensity	%	Developed, Medium Intensity	%	Water	%	Other Urban	%	total
78	524	62%	33	4%	10	1%	21	2%	132	15%	53	6%	31	4%	48	6%	852
79	47	41%	7	6%	1	1%	0	0%	21	18%	5	5%	27	23%	8	6%	116
80	402	34%	79	7%	54	5%	16	1%	264	22%	80	7%	132	11%	148	13%	1,175
85	902	68%	217	16%	122	9%	0	0%	3	0%	2	0%	54	4%	18	1%	1,318
86	658	75%	46	5%	89	10%	0	0%	36	4%	1	0%	34	4%	11	1%	875
87	710	90%	26	3%	15	2%	0	0%	23	3%	0	0%	13	2%	3	0%	791
88	643	70%	111	12%	99	11%	1	0%	4	0%	1	0%	19	2%	44	5%	923
92	764	64%	195	16%	190	16%	0	0%	1	0%	0	0%	25	2%	20	2%	1,195
93	1,355	80%	58	3%	41	2%	0	0%	3	0%	2	0%	172	10%	56	3%	1,687
94	864	62%	98	7%	41	3%	33	2%	45	3%	65	5%	51	4%	189	14%	1,385
95	662	76%	96	11%	88	10%	0	0%	4	0%	0	0%	9	1%	13	1%	872
96	488	65%	108	14%	129	17%	0	0%	17	2%	0	0%	3	0%	7	1%	752
97	437	90%	32	7%	0	0%	0	0%	0	0%	0	0%	15	3%	0	0%	484
98	715	79%	42	5%	80	9%	0	0%	11	1%	0	0%	34	4%	23	3%	904
100	846	80%	59	6%	39	4%	5	0%	13	1%	16	2%	50	5%	28	3%	1,056
101	1,244	53%	139	6%	42	2%	158	7%	137	6%	84	4%	445	19%	78	3%	2,327
102	734	64%	148	13%	75	7%	1	0%	52	5%	10	1%	66	6%	60	5%	1,145
103	602	61%	66	7%	25	3%	2	0%	5	1%	2	0%	269	27%	11	1%	982
104	596	71%	65	8%	23	3%	0	0%	10	1%	0	0%	94	11%	48	6%	837
105	577	79%	60	8%	25	3%	0	0%	1	0%	0	0%	65	9%	3	0%	731
106	792	68%	65	6%	52	4%	1	0%	78	7%	7	1%	94	8%	84	7%	1,171
108	1,328	63%	219	10%	58	3%	1	0%	10	0%	6	0%	413	20%	62	3%	2,097
109	286	51%	17	3%	2	0%	0	0%	0	0%	0	0%	250	45%	1	0%	555
116	816	36%	38	2%	29	1%	29	1%	744	32%	170	7%	148	6%	323	14%	2,297
117	864	50%	9	1%	25	1%	52	3%	320	18%	204	12%	130	8%	124	7%	1,728
118	2,678	70%	238	6%	79	2%	52	1%	197	5%	77	2%	341	9%	159	4%	3,822
119	1,459	73%	71	4%	72	4%	2	0%	19	1%	4	0%	264	13%	106	5%	1,996
Total	88,062		5,440		5,831		949		7,351		2,267		10,003		5,992		125,897
% of Total	70%		4%		5%		1%		6%		2%		8%		5%		100%

3.7 Hydrographic Data

Hydrographic data describing the stream network were obtained from the National Hydrography Dataset (NHD). This data was used for HSPF model development and TMDL development. Stream channels in the hydrologic modeling area were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation using a 0.05 roughness coefficient. Model representation of the stream reach segment is presented in **Appendix A.**

3.8 Fecal Coliform Sources Representation

This section demonstrates how the fecal coliform sources identified in Chapter 2 were included or represented in the model. These sources include permitted sources, human sources (failing sewage disposal systems), livestock, wildlife, pets, and land application of manure.

3.8.1 Permitted Facilities

Based on data obtained from VA DEQ, there are five facilities that are addressed under the Virginia Pollutant Discharge Elimination System (VPDES) Program. The permit number, facility name, design flow and permit concentration (cfu/ 100 ml) for the facilities are presented in **Table 2-8**.

For TMDL development, average discharge flow values were considered representative of flow conditions at the permitted facility, and were used in HSPF model set-up and calibration. For TMDL allocation development, the permitted facility was represented as a constant source discharging at its maximum permitted design flow and bacteria concentration.

3.8.2 Failing Sewage Disposal Systems

Failing sewage disposal system loadings to the watershed can be direct (point) or land-based (indirect or non-point), depending on the proximity of the system to the stream. As explained in Chapter 2, the total number of septic systems in the Tributaries to the Potomac River bacteria impaired watersheds was estimated at 4,763 systems.

For TMDL development, it was assumed that a 3% failure rate for septic systems would be representative of conditions in the watersheds. This corresponds to a total of 143 failed septic systems in the Tributaries to the Potomac River watersheds. The number of houses on other means of sewage disposal (considered to be straight pipes or some sort of alternative disposal system) was estimated by obtaining the ratio of the 1990 "other means" number to the 1990 total households number and multiplying this ratio by the 2009 households estimate. As explained in Chapter 2, the total number of houses on other means in the Tributaries to the Potomac River watersheds was estimated at 277. For TMDL development, the number of failing sewage disposal systems was represented by multiplying the septic failure rate of 3% by the sum of the number of houses on septic systems and the number of houses on "other means." This corresponds to a total of 151 failed sewage disposal systems for the TMDL watersheds.

In each subwatershed, the load from failing sewage disposal systems was calculated as the product of the total number of sewage disposal systems (septic systems and homes on "other means"), estimated failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems' design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100mL (Horsley & Whitten, 1996) were used in the fecal coliform load calculations. Failed sewage disposal systems were represented as constant sources of fecal coliform. **Table 3-3** shows the distribution of the failed sewage disposal systems in the watershed.

Table 3- 3: Failed Septic Systems and Straight Pipes Assumed in Model Development				
Watershed	**Modeling Segment**	**Septic Systems**	**Houses on Other Means**	**Estimated Number of Houses with a Failing Sewage Disposal System (Failing Septic Systems and "Other Means")**
Powells Creek	2	95	3	3
	3	67	2	2
	4	222	6	7
	116	602	16	19
	117	368	10	11
Quantico Creek/South Fork Quantico Creek	5	1	0	0
	6	27	1	1
	7	4	0	0
	8	84	2	3
	9	1	0	0
	10	1	0	0
	12	102	3	3
	13	0	0	0
	14	12	0	0
	16	272	7	8
Chopawamsic Creek	11	4	0	0
	20	0	0	0
Unnamed Tributary to Potomac River	62	179	7	6
Austin Run	65	91	48	4
	66	62	32	3
	67	21	11	1
	76	6	3	0
	78	21	11	1
	79	3	1	0
	80	36	19	2
Accokeek Creek	74	629	24	20
	118	446	17	14
	119	34	1	1
Potomac Creek/Potomac Run	64	4	0	0
	68	61	2	2
	69	0	0	0
	70	2	0	0
	71	5	0	0
	72	16	1	0
	75	7	0	0
	77	29	1	1
	85	7	0	0
	86	54	2	2
	87	34	1	1
	88	9	0	0
	92	2	0	0
	93	7	0	0
	94	211	8	7
	95	6	0	0
	96	26	1	1

Table 3- 3: Failed Septic Systems and Straight Pipes Assumed in Model Development				
Watershed	**Modeling Segment**	**Septic Systems**	**Houses on Other Means**	**Estimated Number of Houses with a Failing Sewage Disposal System (Failing Septic Systems and "Other Means")**
	97	0	0	0
	98	16	1	1
	100	49	2	2
	101	559	21	17
	102	92	4	3
	103	14	1	0
	104	16	1	0
	105	2	0	0
	106	126	5	4
	108	24	1	1
	109	0	0	0
Total		4,768	276	151

[1]Based on a septic failure rate of 3% (VA DEQ 2011)

3.8.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in **Figure 3-3**. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, land-based fecal coliform deposited by livestock while grazing.

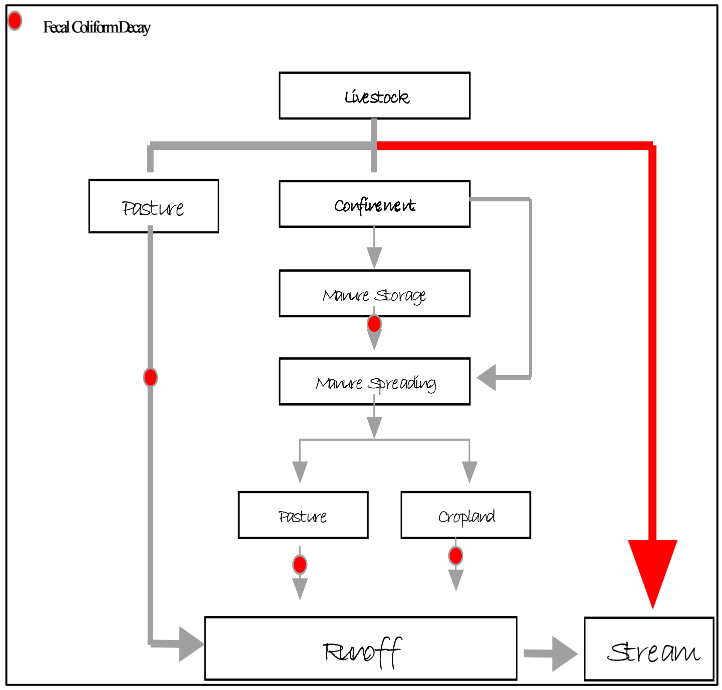

Figure 3- 3: Livestock Contribution to the Impaired TMDL Watersheds

Based on the inventory of livestock in the watershed, it was determined that beef cows, cattle and horses are the predominant types of livestock, though sheep and lambs are also present in the watershed.

The distribution of the daily fecal coliform load between direct instream and indirect (land-based) loading was based on livestock daily schedules. The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in the stream. The amount of time livestock spend in the stream was presented in Chapter 2.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in **Appendix B.**

3.8.4 Land Application of Manure

Beef cattle are present in the watershed. Because there are no feedlots or large manure storage facilities present in the watershed, the daily produced manure is applied to pastureland in the watershed, and was treated as an indirect source in the development of the TMDLs. Beef cattle spend the majority of their time on pastureland and are not confined. Thus, fecal coliform loading from beef cattle was accounted for via the methods described above. Dairy cattle do spend time in confinement, and their fecal coliform load was included in the calculation of land application of manure. Fecal coliform loading from land application of manure was estimated based on the total number of dairy cows in the watershed, the fecal coliform production per animal per day, and the percent of time dairy cows were in confinement.

3.8.5 Wildlife

Fecal loading from wildlife was estimated in the same way as loading from livestock. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on estimates of the amount of time each type of wildlife spends on the surrounding land versus in the stream.

Daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented previously in the wildlife inventory (Chapter 2). The direct fecal coliform load from wildlife was calculated by multiplying the number of each type of wildlife in the watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. Indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the watersheds. The resulting fecal coliform load was then distributed to forest and pasture land uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre), then multiplying the unit loading by the total area of forest and pasture in each subwatershed.

3.8.6 Pets

For the TMDL, pet fecal coliform loading was considered a land-based load that was primarily deposited in urban land within the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per type of pet.

3.9 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the watershed. Three fecal coliform die-off rates required by the model to accurately represent watershed conditions included:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in storage facilities.

2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.

3. **In-stream fecal coliform die-off**. Fecal coliform directly deposited into the stream, as well as fecal coliform entering the stream from indirect sources, will also undergo decay.

For the TMDL, in-storage die-off was not included in the model because there is no manure storage facility located in the watershed. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for onsurface and instream fecal coliform, respectively (EPA, 1985).

3.10 Model Set-up, Hydrology Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to the observed data set, which is different from the one used in the calibration process, and estimates the model's prediction accuracy. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

3.10.1 Model Set-Up

The HSPF model was set up and calibrated first for hydrology used the flow measured at the USGS Station 01660400, Aquia Creek near Garrisonville, VA (**Table 3-4**). As depicted in **Figure 3-2**, there are 4 USGS monitoring flow stations in the study area. The USGS Station 01660400 was selected for the hydrology calibration and validation because it drains a significantly larger area than the 3 other USGS stations and is therefore more amenable to mimic the hydrology in the study area. In fact and following the hydrology calibration and validation, all the derived hydrologic parameters will be assigned to all the other modeling segments for the water quality calibrations and the development of TMDLs. Details on the selected flow monitoring station are presented in **Table 3-4**. **Figure 3-5** depicts the location of USGS Station 01660400 along with the model segments and the weather station used in hydrology modeling.

Table 3- 4: USGS Flow Station used for the Hydrology Calibration and Validation

Station ID	Station Name	Drainage Area (mi^2)	Begin Date	End Date
01660400	Aquia Creek near Garrisonville, VA	35	9/1/1971	10/16/2011

3.10.1.1 Stream Flow Data

A 4-year period (2002-2005) was selected as the calibration period for the hydrologic model. The validation period selected was from 2006 to 2010. Observed flow data for the period of 2002 to 2010 for this station is plotted in **Figure 3-4** and is depicted in **Figure 3-5**

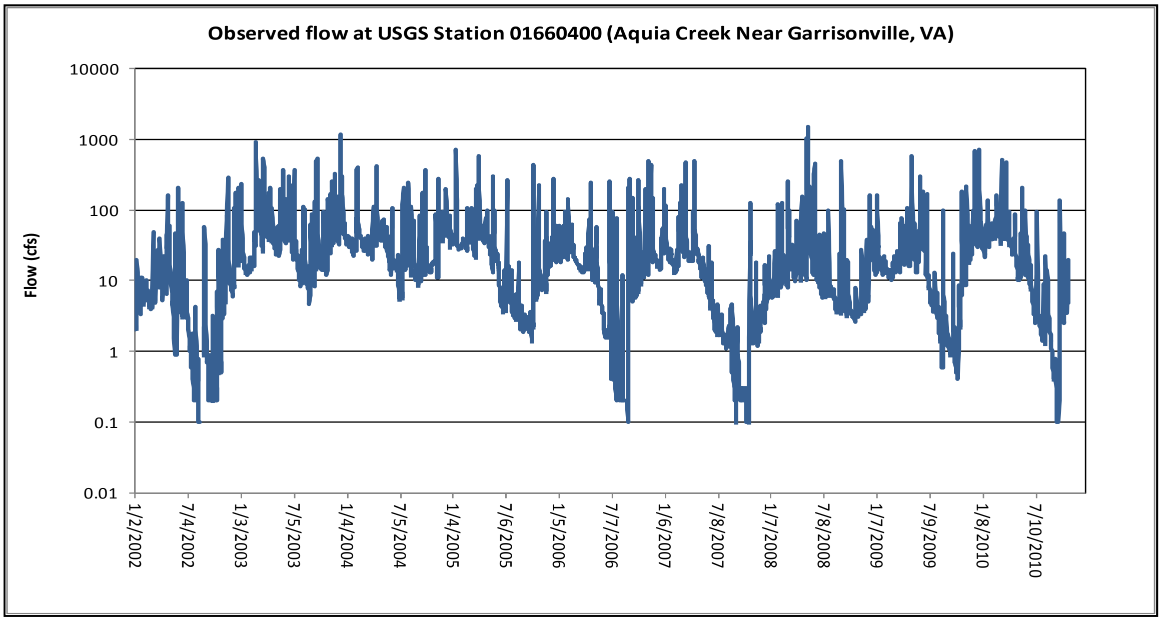

Figure 3- 4: **Daily Mean Flow at USGS Station 01660400 (Aquia Creek near Garrisonville, VA)**

3.10.1.2 Rainfall and Climate Data

Weather data from the Reagan National Airport station were obtained from NCDC. The data include meteorological (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation).

Figure 3- 5: **Locations of NCDC Weather Station and USGS Flow Calibration Station**

3.10.2 Model Hydrologic Calibration Results

The Expert System for Calibration of the Hydrological Simulation Program-FORTRAN (HSPEXP) software was used to calibrate the hydrology of the hydrologic modeling area. After each model's iteration, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended default criteria as target values for an acceptable hydrologic calibration, the hydrologic model was calibrated from January 2002 to December 2005 at the flow stations 01660400 (Aquia Creek near Garrisonville, VA). Calibration results at station USGS 01660400 are presented in **Table 3-4**, showing the simulated and observed values for nine flow characteristics. The error statistics summary for seven flow conditions is presented in **Table 3-5**. The error statistics indicate that the validation results were within the recommended ranges except for the seasonal volume error. The model results and the observed daily average flow at the calibration station are plotted in **Figure 3-6**. The cumulative flow frequency distribution for the calibration period is plotted in Figure **3-8**.

Table 3- 5: USGS 01660400 (Aquia Creek near Garrisonville, VA) Model Calibration Results

Category	Simulated	Observed
Total runoff, in inches	53.490	55.530
Total of highest 10% flows, in inches	24.930	25.151
Total of lowest 50% flows, in inches	8.040	8.757
Total storm volume, in inches	4.020	3.047
Baseflow recession rate	0.910	0.920
Summer flow volume, in inches	11.190	8.658
Winter flow volume, in inches	15.770	17.246

Table 3- 6: USGS 01660400 (Aquia Creek near Garrisonville, VA) Model Calibration Error Statistics		
Category	**Current**	**Criterion**
Error in total volume	-3.700	± 10.000
Error in low flow recession	0.010	± 0.010
Error in 50% lowest flows	-8.200	± 10.000
Error in 10% highest Flow	-0.900	± 15.000
Seasonal volume error	37.8	± 10.000

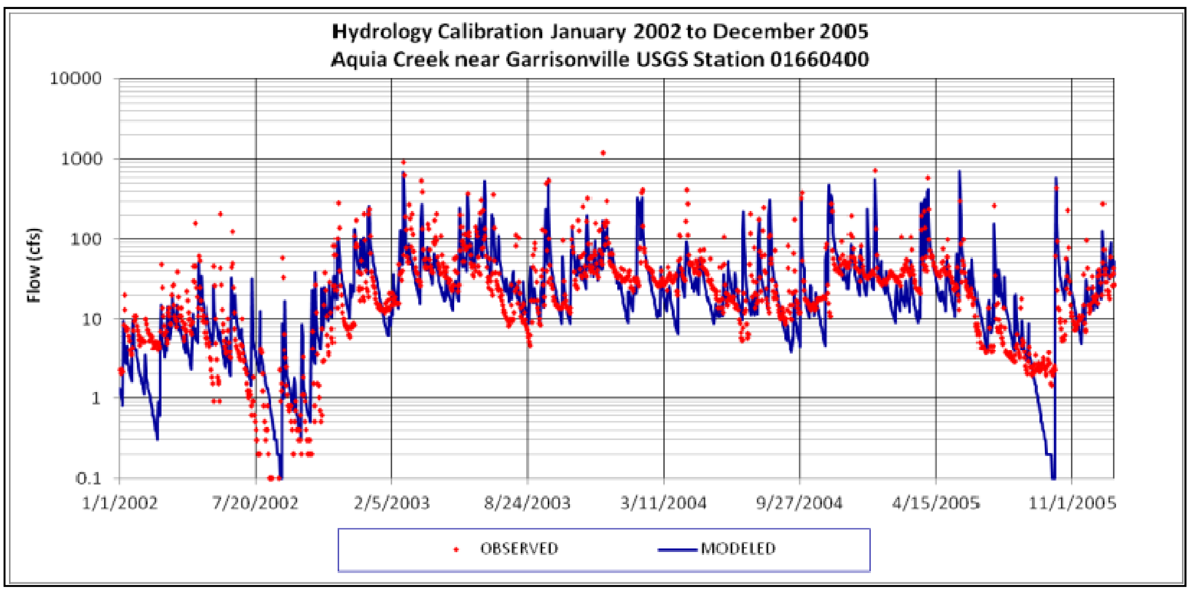

Figure 3- 6: USGS 01660400 (Aquia Creek near Garrisonville, VA) Model Hydrologic Calibration Results

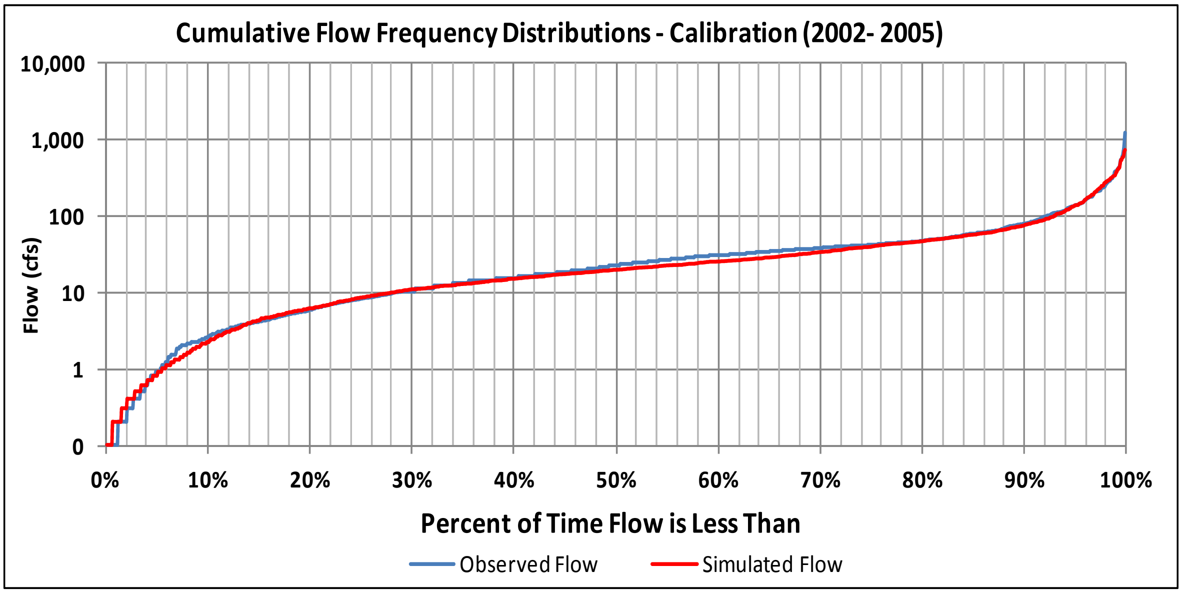

Figure 3- 7: Cumulative Flow Frequency Distribution for Model Hydrologic Calibration Results

3.10.3 Model Hydrologic Validation Results

The period of January 2006 to December 2010 was used to validate the HSPF model. Validation results at USGS Station 01660400 are presented in **Table 3-7**, which shows the simulated and observed values for nine flow characteristics. The error statistics summary for seven flow conditions is presented in **Table 3-8**. The model results and the observed daily average flow at the calibration station are plotted in **Figure 3-8**. The cumulative flow frequency distribution for the validation period is plotted in **Figure 3-9**.

Table 3- 7: USGS 01660400 (Aquia Creek near Garrisonville, VA) Model Validation Results

Category	Simulated	Observed
Total runoff, in inches	42.890	43.14
Total of highest 10% flows, in inches	21.410	24.38
Total of lowest 50% flows, in inches	4.120	3.85
Total storm volume, in inches	4.640	5.38
Baseflow recession rate	0.920	0.91
Summer flow volume, in inches	6.280	5.55
Winter flow volume, in inches	10.380	12.07

Table 3- 8: USGS 01660400 (Aquia Creek near Garrisonville, VA) Model Validation Error Statistics

Category	Current	Criterion
Error in total volume	-0.600	$\pm$ 10.000
Error in low flow recession	-0.010	$\pm$ 0.010
Error in 50% lowest flows	7.100	$\pm$ 10.000
Error in 10% highest Flow	-12.20	$\pm$ 15.000
Seasonal volume error	27.20	$\pm$ 10.000

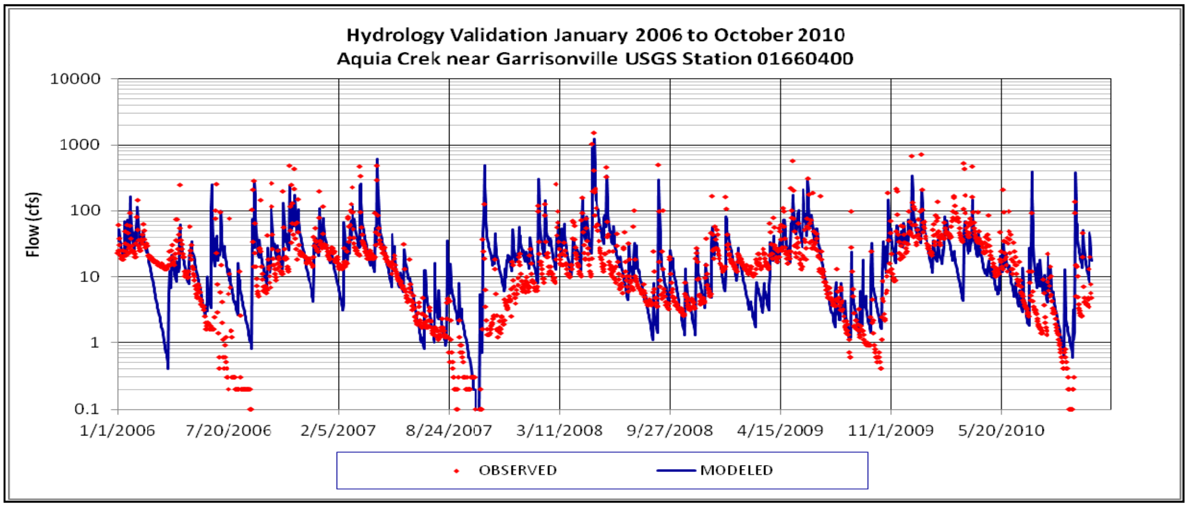

Figure 3- 8: USGS 01660400 (Aquia Creek near Garrisonville, VA) Model Hydrologic Validation Results

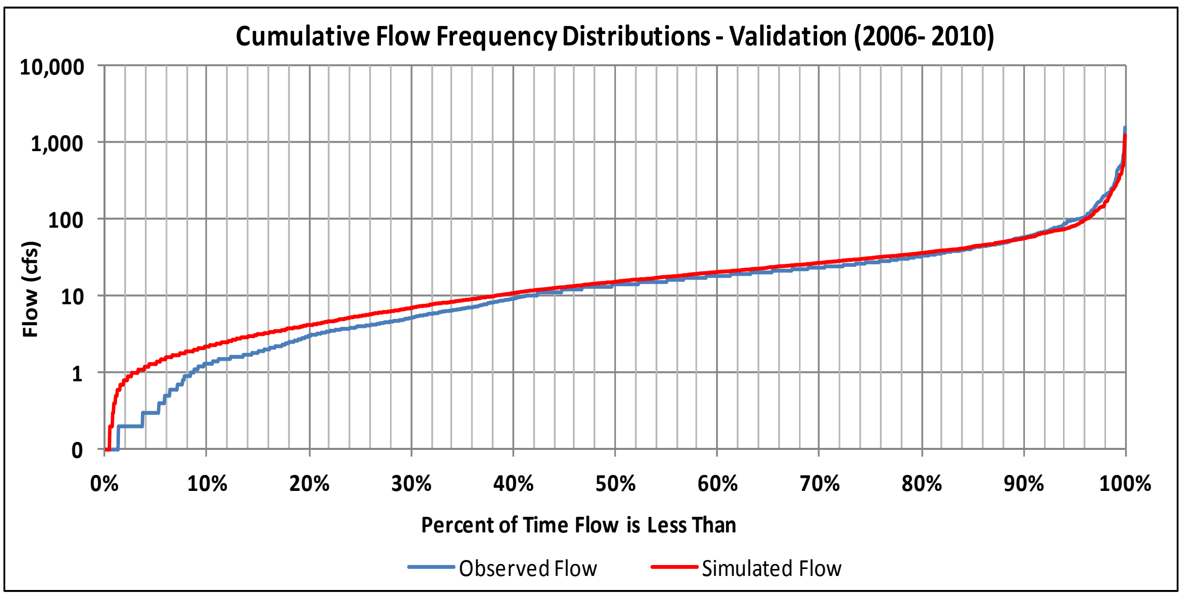

Figure 3- 9: USGS 01660400 (Aquia Creek near Garrisonville, VA) Cumulative Flow Frequency Distribution for Model Hydrologic Validation Results

Overall, there is good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. Model results closely match the observed flows during low flow conditions, base flow recession, and storm peaks.

The error statistics indicate that the calibration and validation results were within the recommended ranges except for the seasonal volume error (**Tables 3-6 and 3-8**). In HSPEXP the seasonal volume error is defined as the summer (June-August) runoff volume percent error minus the winter (December-February) runoff volume error. This relatively high seasonal volume error is caused by the summer flow volume error. In fact, the observed summer flow is extremely low (as low as 0.1 cfs) and an extremely small difference between the computed summer flow and the observed summer flow results in a significantly high summer flow percent error. The final parameter values of the calibrated hydrology model are listed in **Table 3-9**.

Table 3- 9: TMDL HSPF Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Tributaries to the Potomac River: Prince William and Stafford County
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0.00	0.5	0	1.0	0 - 1
LZSN	Lower zone nominal soils moisture	inch	3	8	0.01	100	8.0 - 9.3
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.0001	100	0.05 - 0.11
LSUR	Length of overland flow	ft	200	500	1	None	300
SLSUR	Slope of overland flowpath	None	0.01	0.15	0.00001	10	0.012
KVARY	Groundwater recession variable	1/inch	0	3	0	None	0
AGWRC	Basic groundwater recession	None	0.92	0.99	0.001	0.999	0.88 - 0.905
PETMAX	Air temp below which ET is reduced	Deg F	35	45	None	None	40

PETMIN	Air temp below which ET is set to zero	Deg F	30	35	None	None	35
INFEXP	Exponent in infiltration equation	None	2	2	0	10	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	2	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	1.0	0.25
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	1.0	0
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	1.0	0
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.00	10.0	0.06
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.01	10.0	0.3
NSUR	Manning's n	None	0.15	0.35	0.001	1.0	0.1 - 0.35
INTFW	Interflow/surface runoff partition parameter	None	1	3	0	None	3 - 4
IRC	Interflow recession parameter	None	0.5	0.7	0.001	0.999	0.3
LZETP	Lower zone ET parameter	None	0.2	0.7	0.0	0.999	0.3 - 0.66
ACQOP*	Rate of accumulation of constituent	#/ac day					1.09E05 - 1.10E11
SQOLIM*	Maximum accumulation of constituent	#					1.96E05 - 1.98E11
WSQOP*	Wash-off rate	Inch/hour					0.45 - 1
IOQC*	Constituent concentration in interflow	#/CF					1416
AOQC*	Constituent concentration in active groundwater	#/CF					283
KS*	Weighing factor for hydraulic routing		0.5				0.5
FSTDEC*	First order decay rate of the constituent	1/day	1.152 (FC)				1.152
THFST*	Temperature correction coefficient for FSTDEC	none	1.07				1.07

*Typical values. These parameters are unavailable because they are site-specific and determined through model calibration.

3.10.4 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off, and kinetic rates for fecal coliform that best describe fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available instream fecal coliform data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated instream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The availability of water quality data is a major factor in determining calibration and validation periods for the model. In Chapter 2, instream monitoring stations on the impaired segments were listed and sampling events conducted on Powells Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run were summarized and presented. **Table 3-10** lists the stations used in the water quality calibration for each impaired segment.

Table 3- 10: Water Quality Stations used in the HSPF Fecal Coliform Simulations

Stream	Water Quality Station	HSPF Model Segment
Powells Creek	1APOW003.11	117
Quantico Creek	1AQUA004.46	16
South Fork Quantico Creek	1ASOQ006.73	10
North Branch Chopawamsic Creek	1ANOR009.87	11
Unnamed Tributary to Potomac River	1AXLF000.13	62
Austin Run	1AAUS000.49	80
Accokeek Creek	1AACC006.13	118
Potomac Creek	1APOM006.72	108
Potomac Run	1APOR000.40	70

The period used for water quality calibration of the model, and the period used for model validation depended on the time the water quality observations were collected. It is important to keep in mind that the observed *E.* coli concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model simulates fecal coliform concentrations since all the source assessment and model input parameters were based on fecal coliform. The *E. coli* concentrations in the impaired segments were then calculated from the simulated fecal coliform concentrations using a regression based instream translator, which is presented below:

$$E.\ coli\ concentration\ (cfu/100\ ml) = 2^{-0.0172}\ x\ (FC\ concentration\ (cfu/100ml))^{0.91905}$$

These E. coli concentrations were then compared to the E. coli concentrations measured at the various VADEQ monitoring stations in each of the impaired segment. **Figures 3-9 through 3-17** summarize the calibration results of the HSPF *E*. coli simulations.

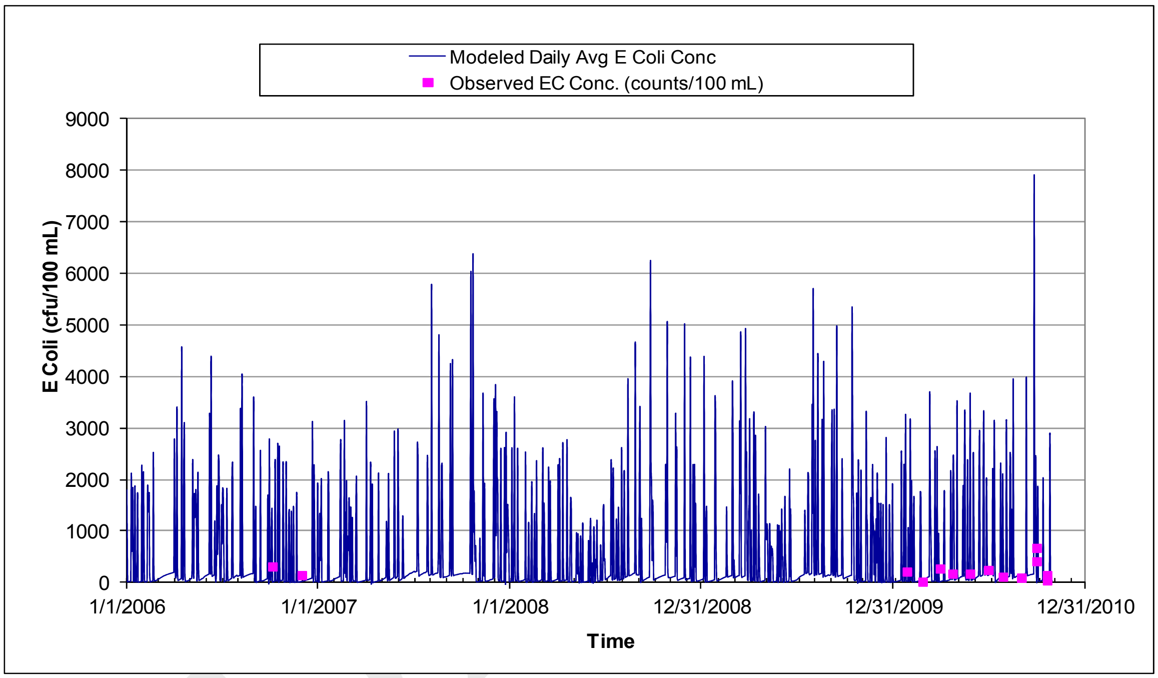

Figure 3- 10: *E. coli* Calibration for Powells Creek - 1APOW003.11 (Reach 117)

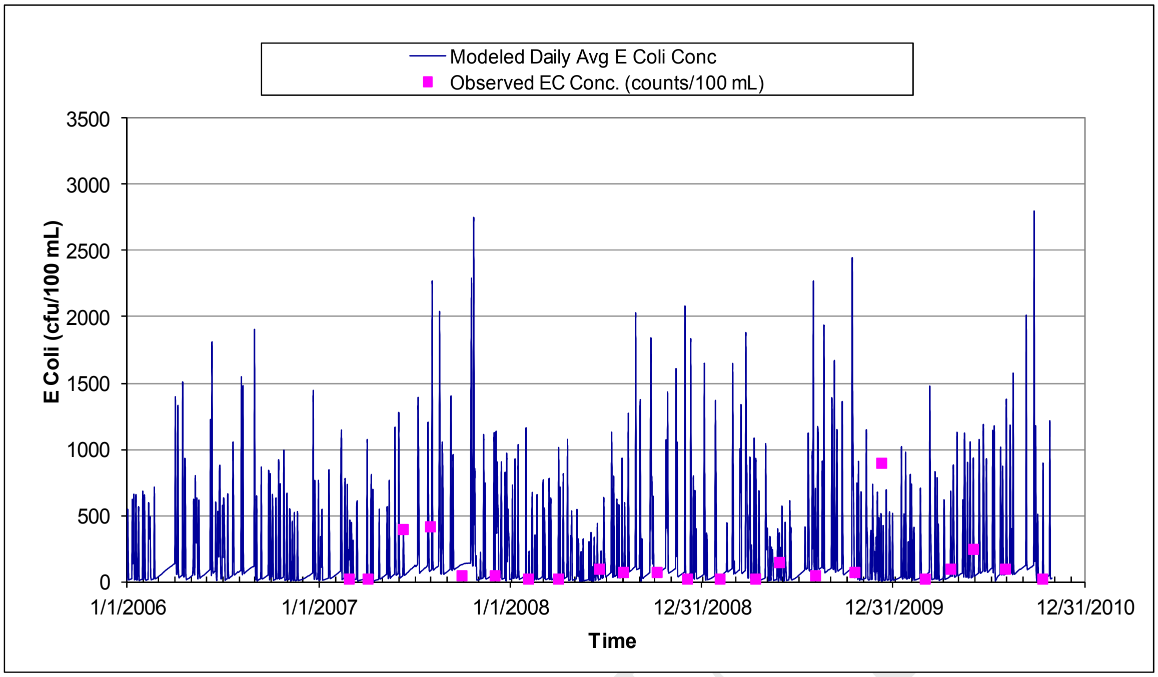

Figure 3- 11: *E.* coli Calibration for Quantico Creek - 1AQUA004.46 (Reach 16)

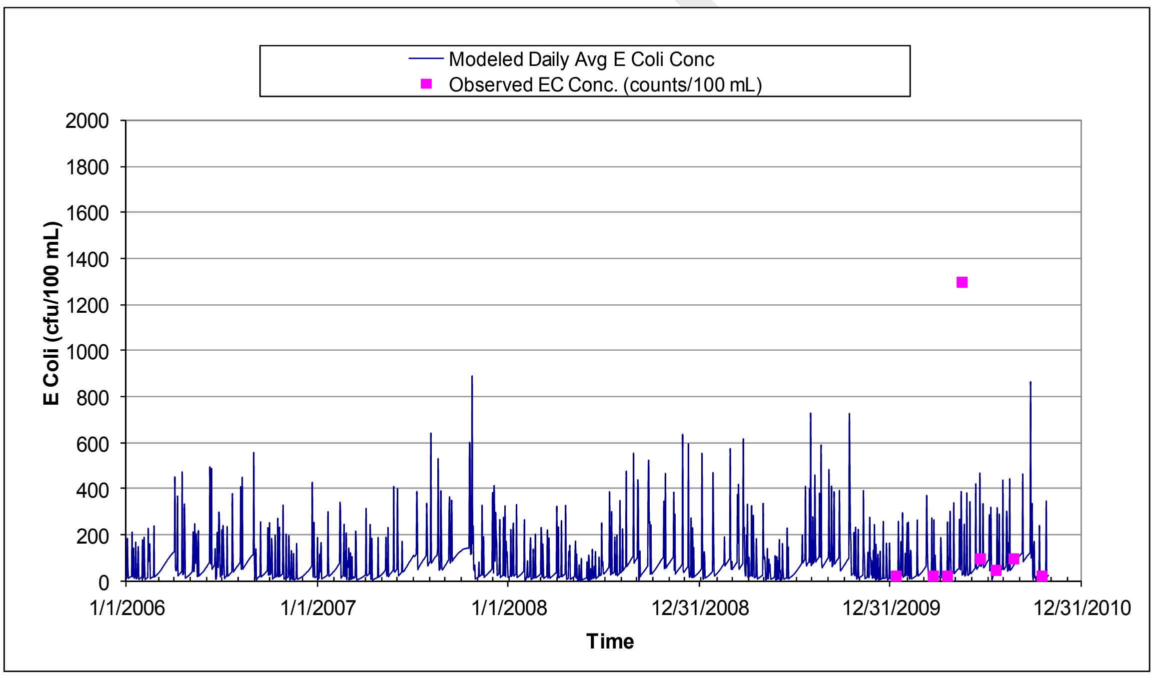

Figure 3- 12: *E. coli* Calibration for South Fork Quantico Creek - 1ASOQ006.73 (Reach 10)

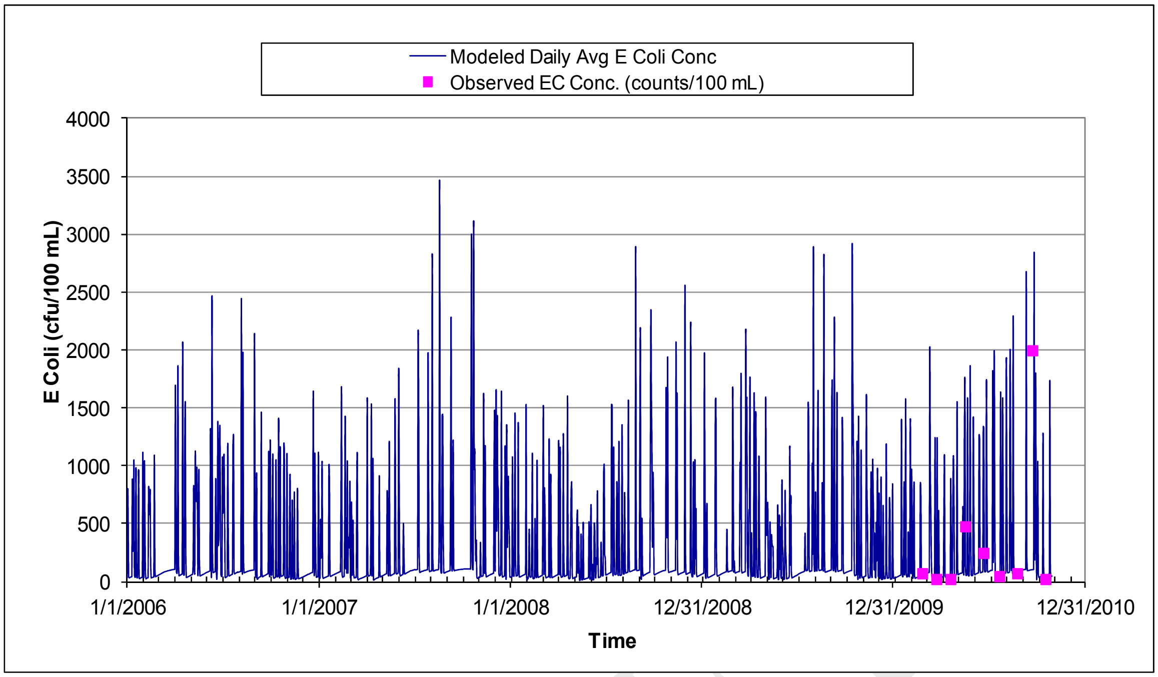

Figure 3- 13: *E. coli* Calibration for North Branch Chopawamsic Creek - 1ANOR009.87 (Reach 11)

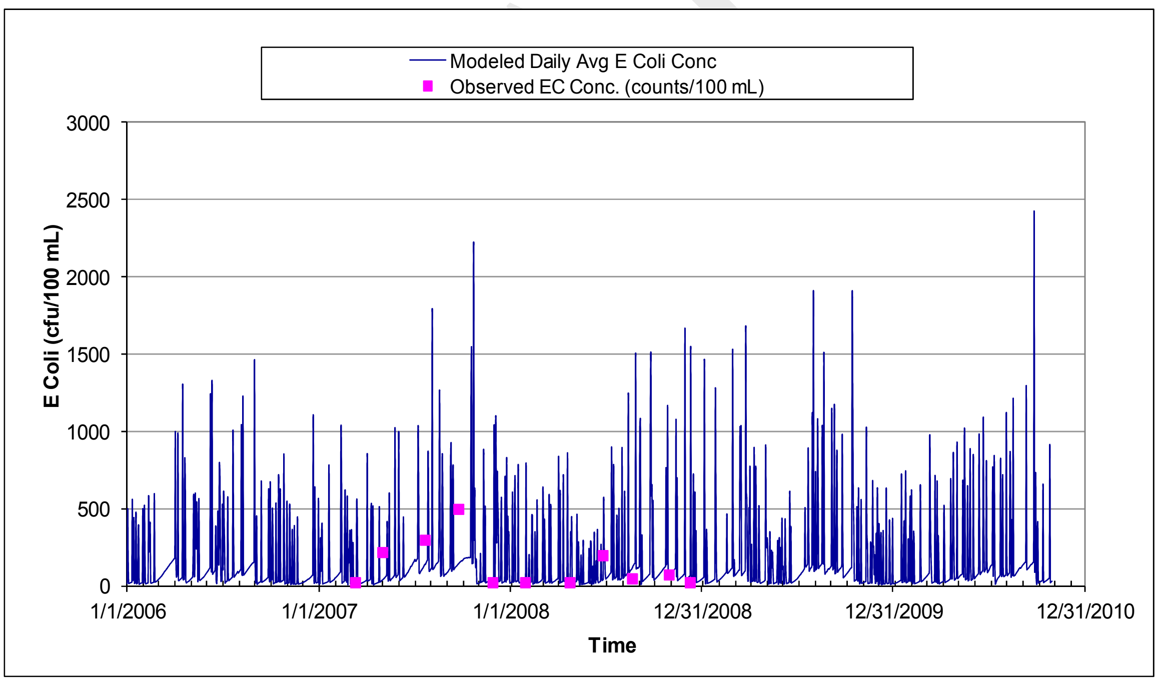

Figure 3- 14: *E. coli* Calibration for an Unnamed Tributary to Potomac River - 1AXLF000.13 (Reach 62)

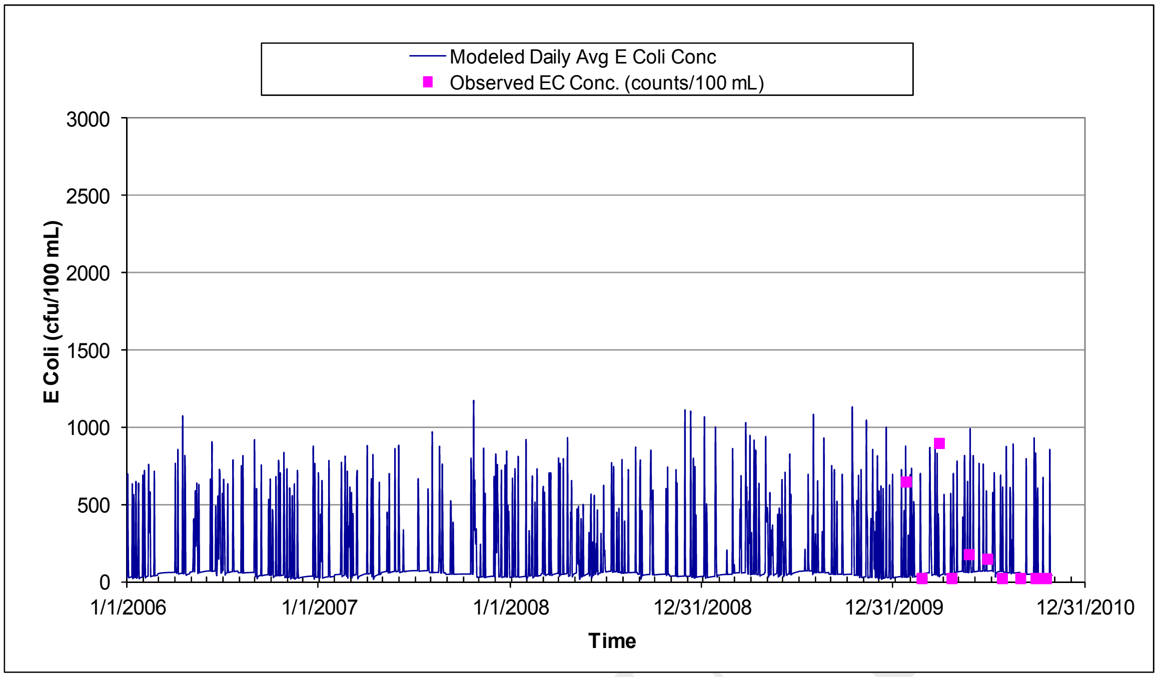

Figure 3- 15: *E. coli* Calibration for Austin Run - 1AAUS000.49 (Reach 80)

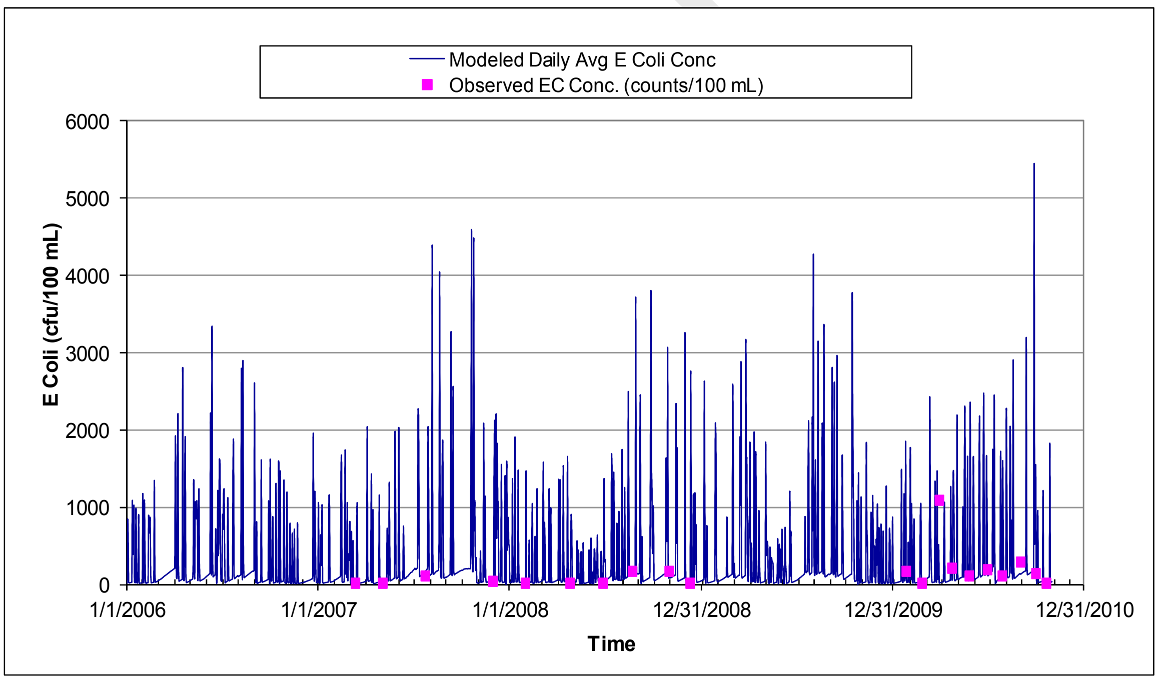

Figure 3- 16: *E. coli* Calibration for Accokeek Creek - 1ADIF000.86 (Reach 118)

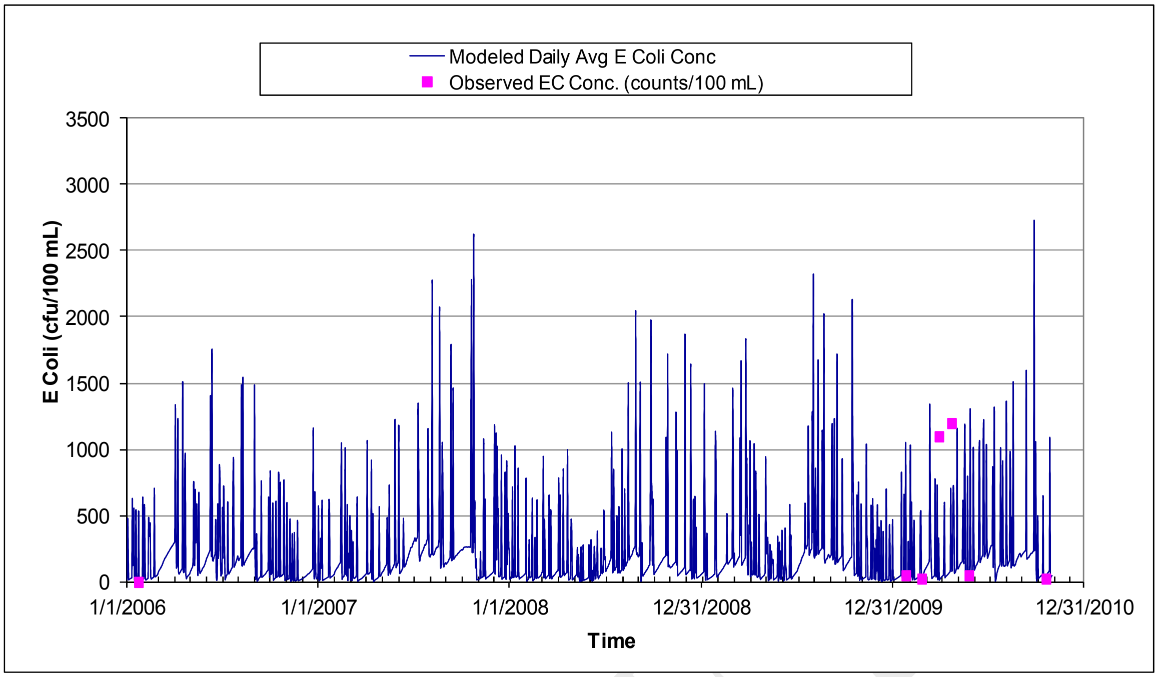

Figure 3- 17: *E. coli* Calibration for Potomac Creek - 1AACC006.13 (Reach 108)

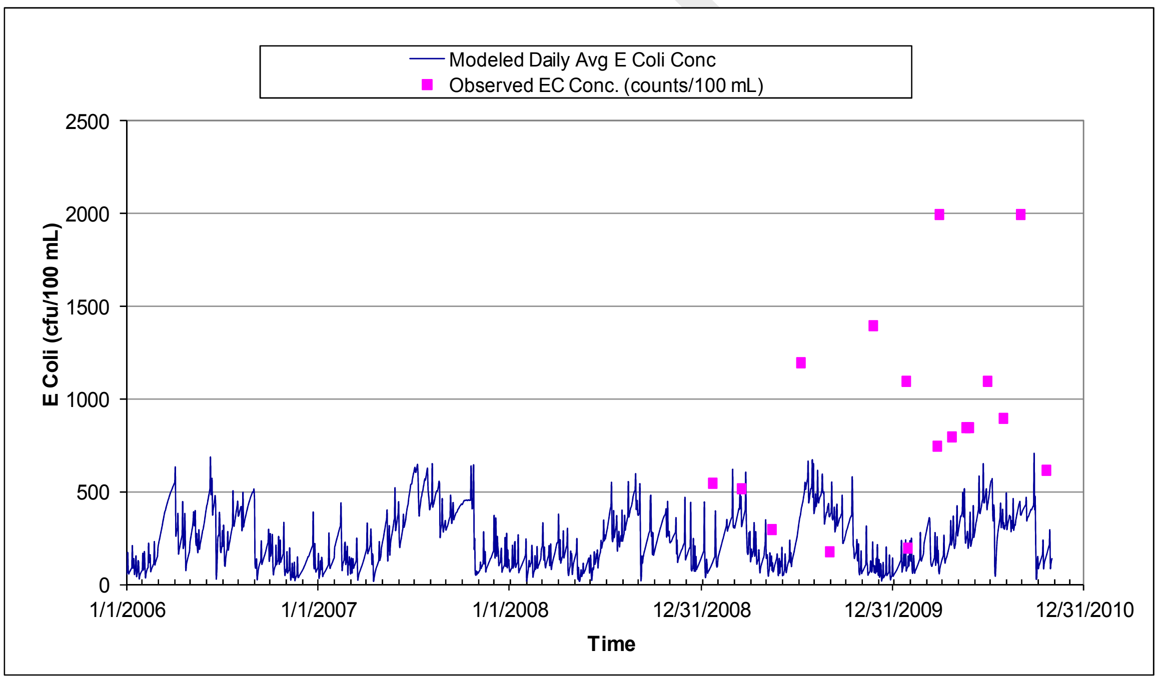

Figure 3- 18: *E. coli* Calibration for Potomac Run - 1APOR000.40 (Reach 70)

The goodness of fit for the water quality calibration was evaluated visually. Analysis of the model results indicated that the model was capable of predicting the range of fecal coliform concentrations under both wet and dry weather conditions, and thus was well-calibrated. **Table 3-11** shows the observed and simulated exceedance rates of the geometric mean *E. coli* concentration spanning the period from 2006 to 2010. Similarly, **Table 3-12** shows the observed and simulated exceedance rates of the 235 cfu/100 ml maximum *E. coli* criterion.

Table 3- 11: Observed and Simulated Geometric Mean *E. coli* Concentration

Station	Reach	Exceedances of the Geometric Mean Standard*	
		Simulated	Observed
Powells Creek - 1APOW003.11	117	140	143
Quantico Creek - 1AQUA004.46	16	70	82
South Fork Quantico Creek - 1ASOQ006.73	10	54	63
North Branch Chopawamsic Creek - 1ANOR009.87	11	102	101
Unnamed Tributary to Potomac River - 1AXLF000.13	62	68	71
Austin Run - 1AAUS000.49	80	72	72
Accokeek Creek - 1AACC006.13	118	102	104
Potomac Creek - 1APOM006.72	108	105	101
Potomac Run - 1APOR000.40	70	548	621
*126 cfu/100ml			

Table 3- 12: Observed and Simulated Exceedance Rates of the 235 cfu/100ml Maximum Assessment Criterion for *E. coli* Bacteria.

Station	Reach	Exceedances of the Maximum Assessment Criterion*	
		Simulated	Observed
Powells Creek - 1APOW003.11	117	32%	31%
Quantico Creek - 1AQUA004.46	16	26%	24%
South Fork Quantico Creek - 1ASOQ006.73	10	20%	13%
North Branch Chopawamsic Creek - 1ANOR009.87	11	29%	33%
Unnamed Tributary to Potomac River - 1AXLF000.13	62	25%	18%
Austin Run - 1AAUS000.49	80	23%	20%
Accokeek Creek - 1AACC006.13	118	31%	18%
Potomac Creek - 1APOM006.72	108	35%	32%
Potomac Run - 1APOR000.40	70	84%	83%
*235 cfu/100ml			

3.11 Existing Bacteria Loading

The existing fecal coliform loading for each of the impaired watershed was calculated based on current watershed conditions represented by the water quality calibrations.

3.11.1 Powells Creek

The instream concentration of bacteria under existing conditions in the Powells Creek mainstem is above both the fecal coliform and *E. coli* geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-19** shows the *E. coli* geometric mean concentrations under existing conditions and **Figure 3-20** shows the *E. coli* instantaneous concentrations under existing conditions.

Distribution of the existing fecal coliform load by source in Powells Creek (Segment VAN-A26R_POW01A00) is presented in **Table 3-13**. *E. coli* concentrations in the impaired Powells Run segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-13** shows that loadings from residential areas (which includes the fecal coliform load from pets), as well as indirect loading from forest (which includes fecal coliform load from wildlife) and pasture (which includes the fecal coliform load from wildlife and cattle), are the predominant sources of bacteria in the Powells Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife will dominate. Under dry weather conditions, direct deposition loads from wildlife will dominate.

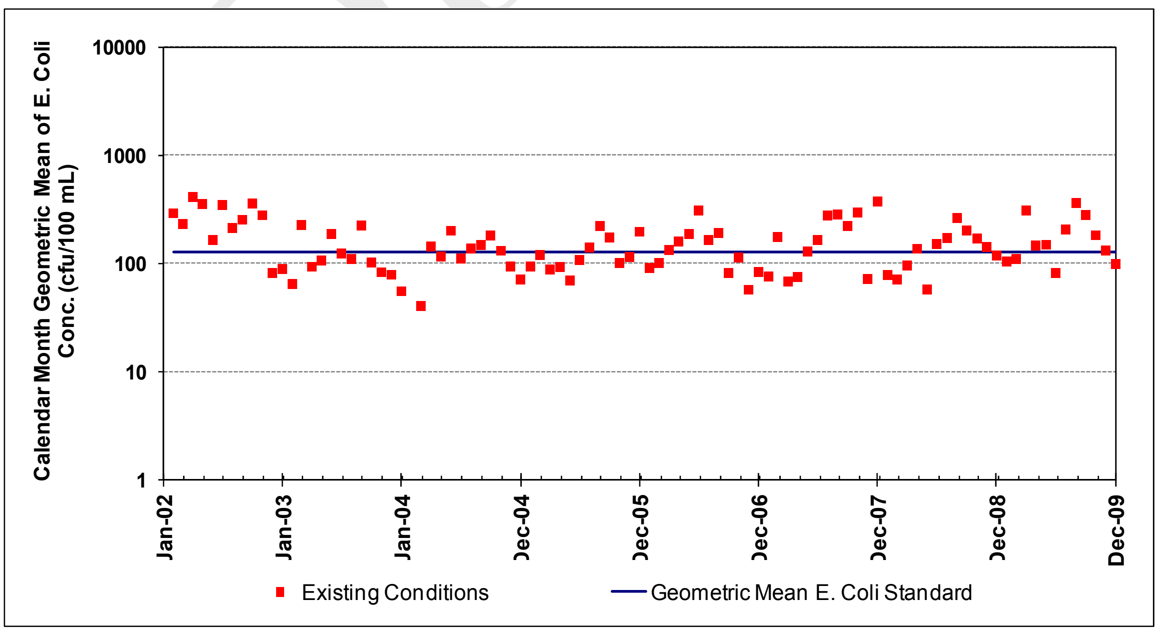

Figure 3- 19: **Powells Creek *E. coli* Geometric Mean Existing Conditions**

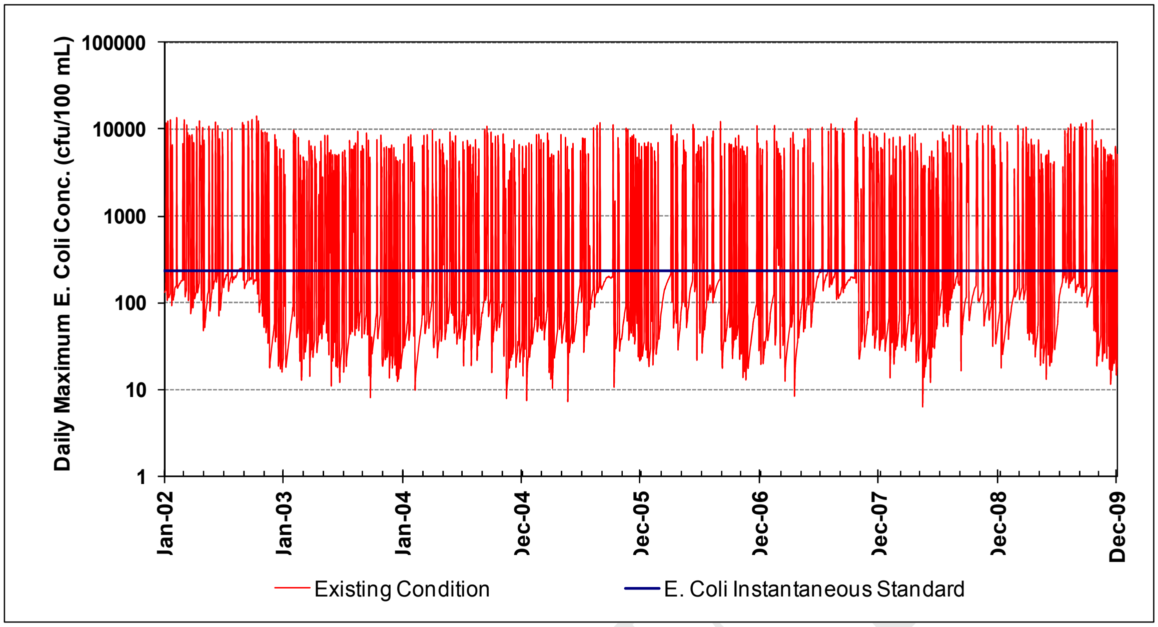

Figure 3- 20: Powells Creek *E. coli* Instantaneous Existing Conditions

Table 3- 13: Powells Creek (Segment VAN-A26R-POW01A00) *E. coli* Existing Load Distribution

Source	Annual Average *E. Coli* Loads	
	cfu/year	%
Forest	1.49E+13	9.9%
Cropland	1.44E+12	1.0%
Pasture	1.36E+13	9.1%
Urban	1.15E+14	76.6%
Cattle - Direct Deposition	2.09E+12	1.4%
Wildlife-Direct Deposition	2.62E+12	1.7%
Failed Septics	4.04E+11	0.3%
Point Source	0.00E+00	0.0%
Total	1.50E+14	100.0%

3.11.2 Quantico Creek

The instream concentration of bacteria under existing conditions in the Quantico Creek mainstem is above both the fecal coliform and *E. coli* geometric mean and maximum assessment criteria for the majority of the time period**. Figure 3-21** shows the *E. coli* geometric mean concentrations under existing conditions and **Figure 3-22** shows the *E. coli* instantaneous concentrations under existing conditions.

Distribution of the existing *E. coli* load by source in Quantico Creek (segment VAN-A26R-QUA01A00) is presented in **Table 3-14**. *E. coli* concentrations in the impaired Quantico Creek segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-14** shows that loadings from residential areas (which includes the fecal coliform load from pets), as well as indirect loads from forest (which includes the fecal coliform load from wildlife) and direct loads from wildlife, are the predominant sources of bacteria in Quantico Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife will dominate. Under dry weather conditions, the direct deposition loads from wildlife will dominate.

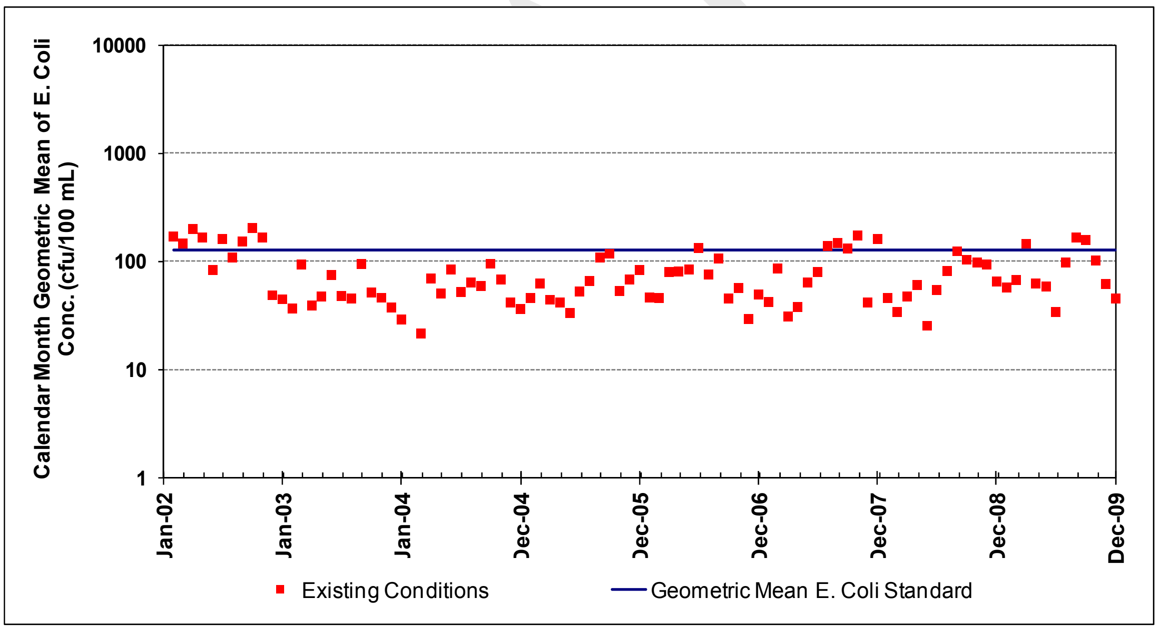

Figure 3- 21: Quantico Creek *E. coli* Geometric Mean Existing Conditions

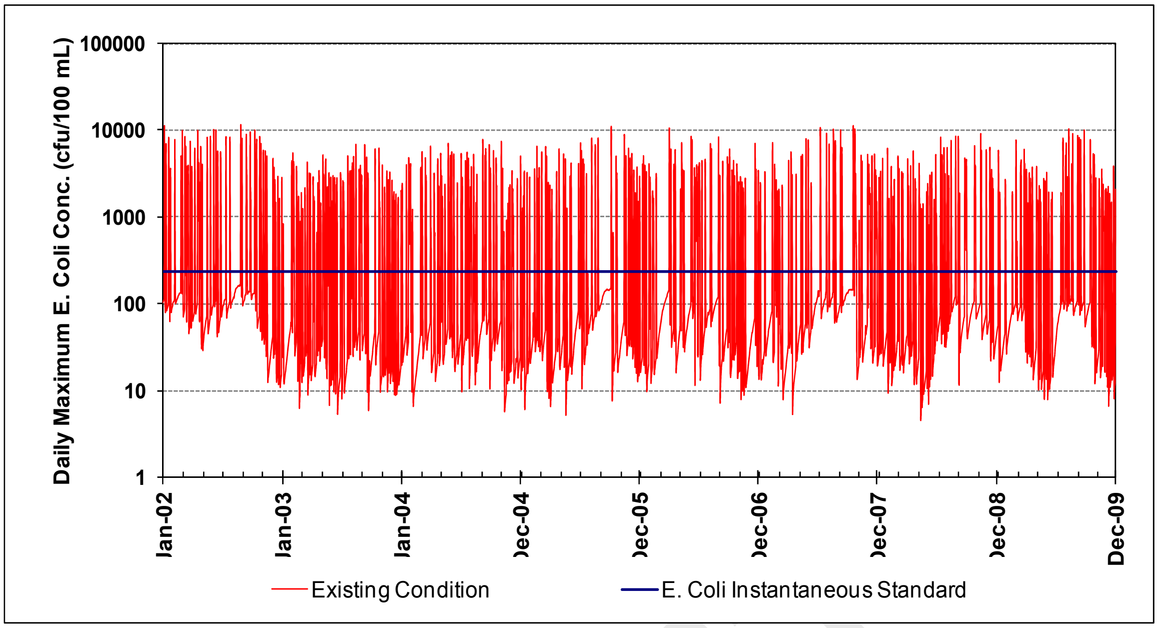

Figure 3- 22: Quantico Creek *E. coli* Instantaneous Existing Conditions

Table 3- 14: Quantico Creek (Segment VAN-A26R-QUA01A00) Fecal Coliform Existing Load Distribution

Source	Annual Average *E. coli* Loads	
	cfu/year	**%**
Forest	7.59E+12	7.8%
Cropland	6.88E+10	0.1%
Pasture	4.21E+10	0.0%
Urban	8.64E+13	89.3%
Cattle - Direct Deposition	2.34E+10	0.0%
Wildlife-Direct Deposition	2.47E+12	2.5%
Failed Septics	1.37E+11	0.1%
Point Source	0.00E+00	0.0%
Total	9.67E+13	100.0%

3.11.3 South Fork Quantico Creek

The instream concentration of bacteria under existing conditions in the South Fork Quantico Creek mainstem is above both the fecal coliform and E. coli geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-23** shows the E. coli geometric mean concentrations under existing conditions and **Figure 3-24** shows the E. coli instantaneous concentrations under existing conditions. .

Distribution of the existing *E. coli* load by source in South Fork Quantico Creek (segment VAN-A26R-SOQ01B02) is presented in **Table 3-15**. E. coli concentrations in the impaired South Fork Quantico Creek segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-15** shows that indirect loads from forest (which includes the fecal coliform load from wildlife) and direct loadings from wildlife, as well as direct loading from cattle, are the predominant sources of bacteria in South Fork Quantico Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from wildlife will dominate. Under dry weather conditions, the direct deposition loads from wildlife and cattle will dominate.

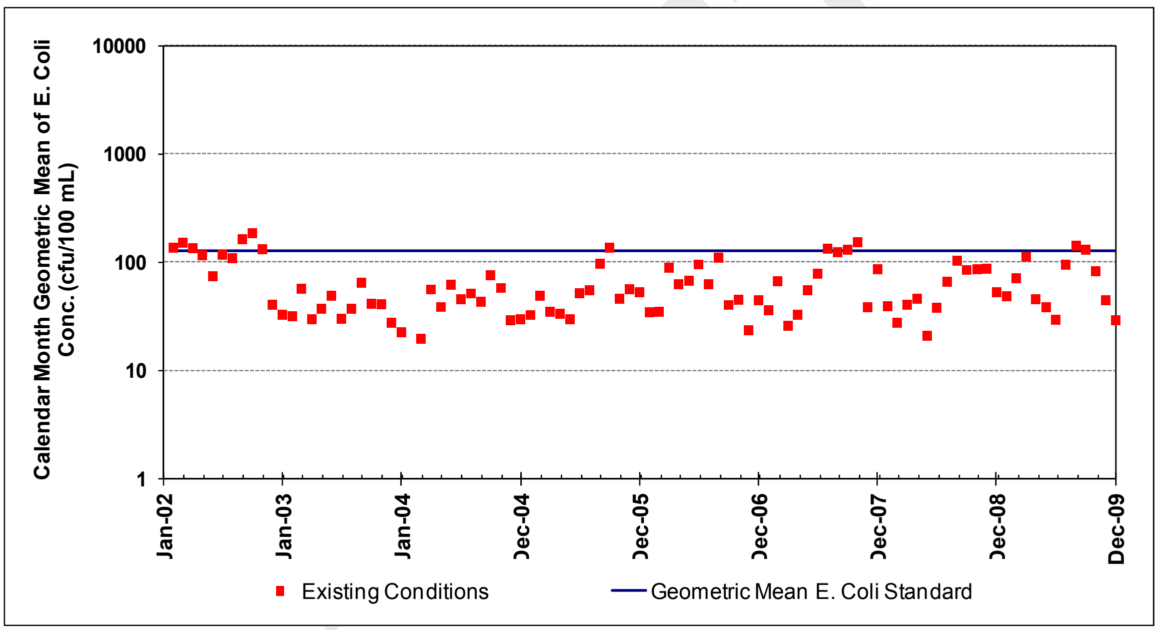

Figure 3- 23: South Fork Quantico Creek *E. coli* Geometric Mean Existing Conditions

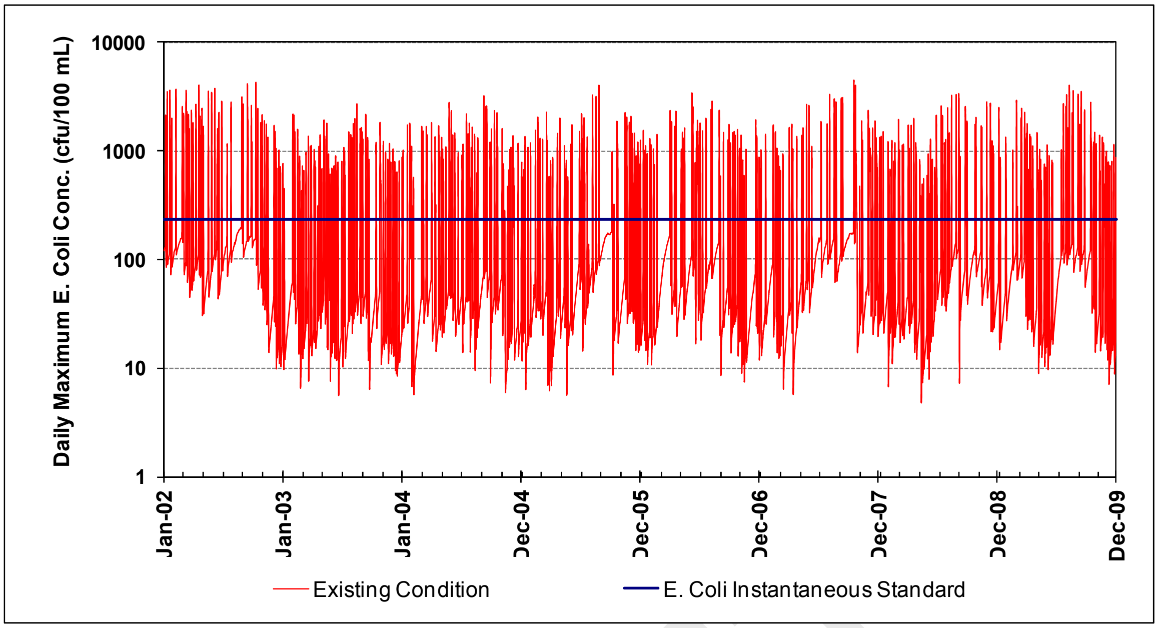

Figure 3- 24: South Fork Quantico Creek *E. coli* Instantaneous Existing Conditions

Table 3- 15: South Fork Quantico Creek (Segment VAN-A26R-SOQ01B02) *E. coli* Existing Load Distribution

Source	Annual Average *E. coli* Loads	
	cfu/year	%
Forest	6.09E+12	80.4%
Cropland	1.78E+09	0.0%
Pasture	3.94E+08	0.0%
Urban	1.83E+11	2.4%
Cattle - Direct Deposition	2.37E+09	0.0%
Wildlife-Direct Deposition	1.30E+12	17.1%
Failed Septics	5.52E+09	0.1%
Point Source	0.00E+00	0.0%
Total	7.58E+12	100%

3.11.4 North Branch Chopawamsic Creek

The instream concentration of bacteria under existing conditions in the North Branch Chopawamsic Creek mainstem is above both the fecal coliform and E. coli geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-25** shows the E. coli geometric mean concentrations under existing conditions and **Figure 3-26** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing *E. coli* load by source in North Branch Chopawamsic Creek (segment VAN-A26R-NOR01A02) is presented in **Table 3-16**. E. coli concentrations in the impaired North Branch Chopawamsic Creek segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-16** shows that indirect loadings from forest (which includes the fecal coliform load from wildlife) as well as direct loadings from wildlife are the predominant sources of bacteria in North Branch Chopawamsic Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from wildlife will dominate. Under dry weather conditions, the direct deposition loads from wildlife will dominate.

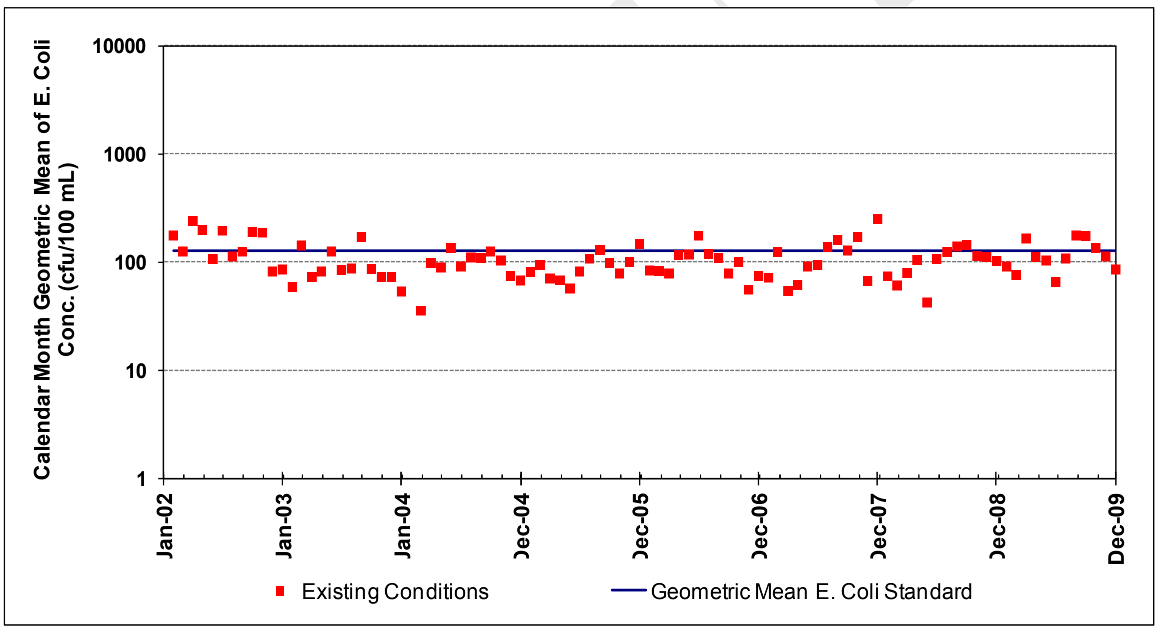

Figure 3- 25: North Branch Chopawamsic Creek *E. coli* Geometric Mean Existing Conditions

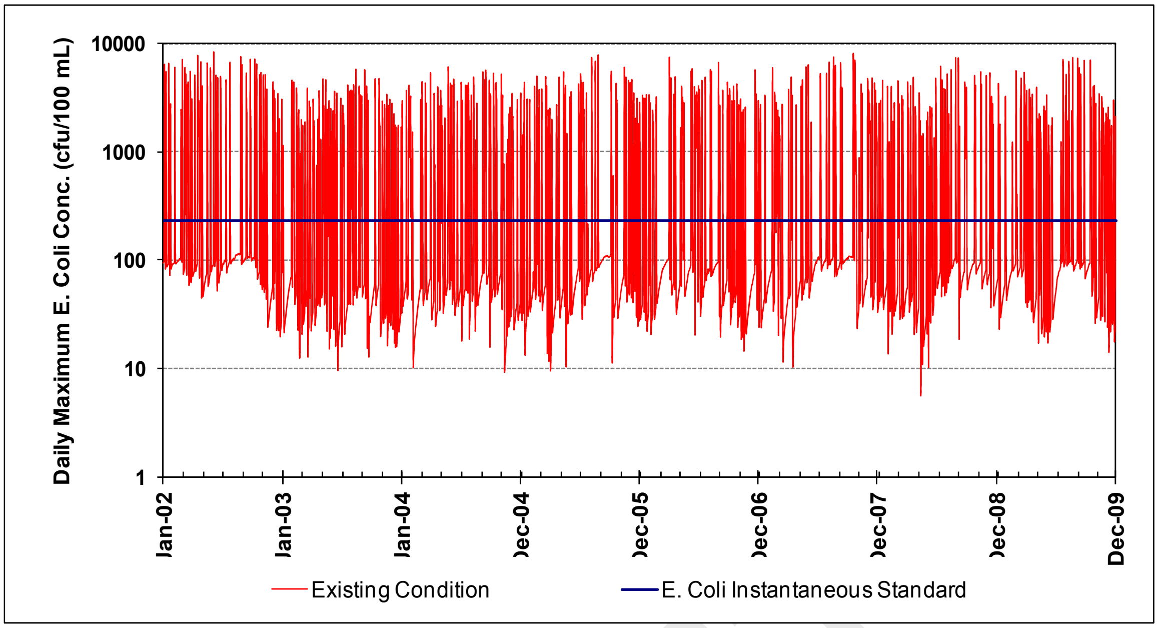

Figure 3- 26: North Branch Chopawamsic Creek *E. coli* Instantaneous Existing Conditions

Table 3- 16: North Branch Chopawamsic Creek (Segment VAN-A26R-NOR01A02) *E. coli* Existing Load Distribution

Source	Annual Average *E. coli* Loads	
	cfu/year	%
Forest	2.60E+13	90.5%
Cropland	1.98E+09	0.0%
Pasture	4.15E+08	0.0%
Urban	5.93E+11	2.1%
Cattle - Direct Deposition	0.00E+00	0.0%
Wildlife-Direct Deposition	2.12E+12	7.4%
Failed Septics	0.00E+00	0.0%
Point Source	0.00E+00	0.0%
Total	2.87E+13	100.0%

3.11.5 Unnamed Tributary to Potomac River

The instream concentration of bacteria under existing conditions in the Unnamed Tributary to Potomac River mainstem is above both the fecal coliform and E. coli geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-27** shows the E. coli geometric mean concentrations under existing conditions and **Figure 3-28** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing *E. coli* load by source in Unnamed Tributary to Potomac River (segment VAN-A26R-XLF01A10) is presented in **Table 3-17**. E. coli concentrations in the impaired South Fork Quantico Creek segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-17** shows that indirect loadings from forest (which includes the fecal coliform load from wildlife) and loadings from residential areas (which includes the bacteria load from pets), as well as direct deposition from wildlife, are the predominant sources of bacteria in Unnamed Tributary to Potomac River watershed. Dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition loads from wildlife will dominate.

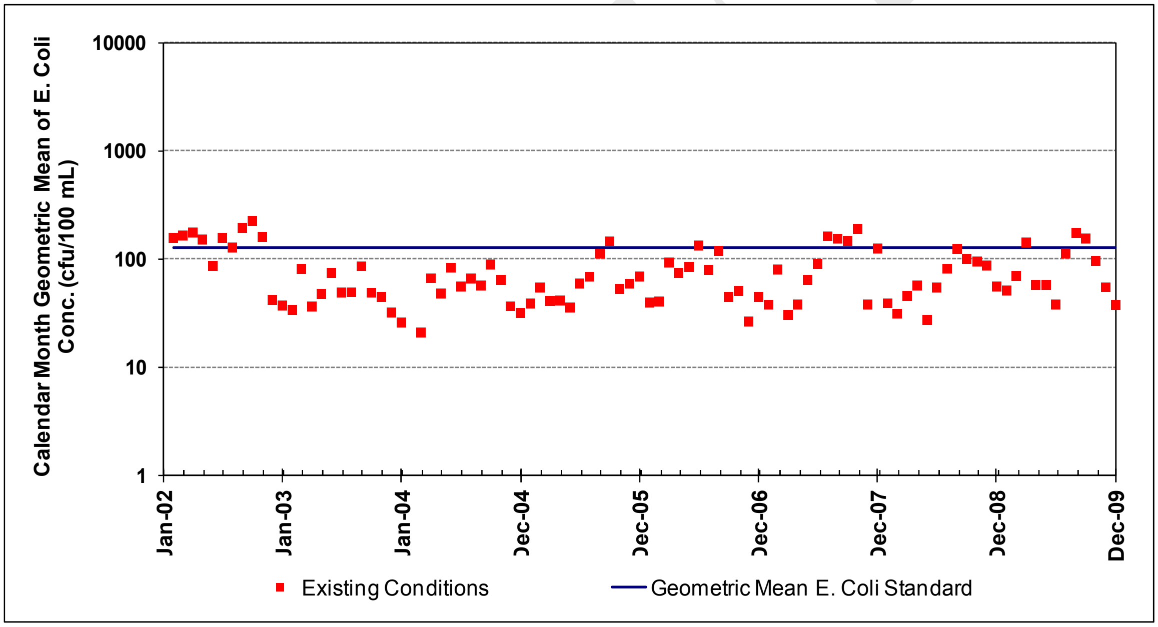

Figure 3- 27: Unnamed Tributary to Potomac River *E. coli* Geometric Mean Existing Conditions

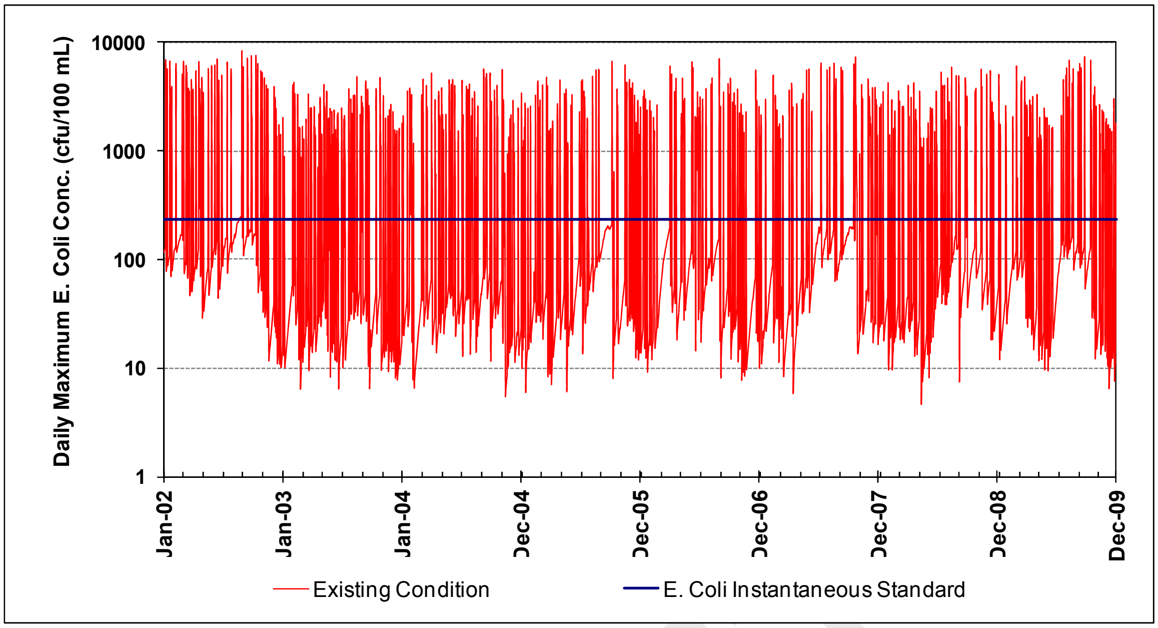

Figure 3- 28: Unnamed Tributary to Potomac River *E. coli* Instantaneous Existing Conditions

Table 3- 17: Unnamed Tributary to Potomac River (Segment VAN-A26R-XLF01A10) *E. coli* Existing Load Distribution

Source	Annual Average *E. coli* Loads	
	cfu/year	**%**
Forest	5.17E+12	52.5%
Cropland	1.70E+09	0.0%
Pasture	1.07E+09	0.0%
Urban	3.90E+12	39.7%
Cattle - Direct Deposition	1.08E+09	0.0%
Wildlife-Direct Deposition	6.90E+11	7.0%
Failed Septics	7.45E+10	0.8%
Point Source	1.74E+09	0.0%
Total	9.85E+12	100.0%

3.11.6 Austin Run

The instream concentration of bacteria under existing conditions in the Austin Run mainstem is above both the fecal coliform and E. coli geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-29** shows the E. coli geometric mean concentrations under existing conditions and **Figure 3-30** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing *E. coli* load by source in Austin Run (segment VAN-A28R-AUS01A04) is presented in **Table 3-18** and indicates that indirect loadings from forest (which includes the bacteria load from wildlife) as well as loadings from residential areas (which includes the fecal coliform load from pets) are the predominant sources of bacteria in Austin Run watershed. Wet weather conditions were identified as the critical condition.

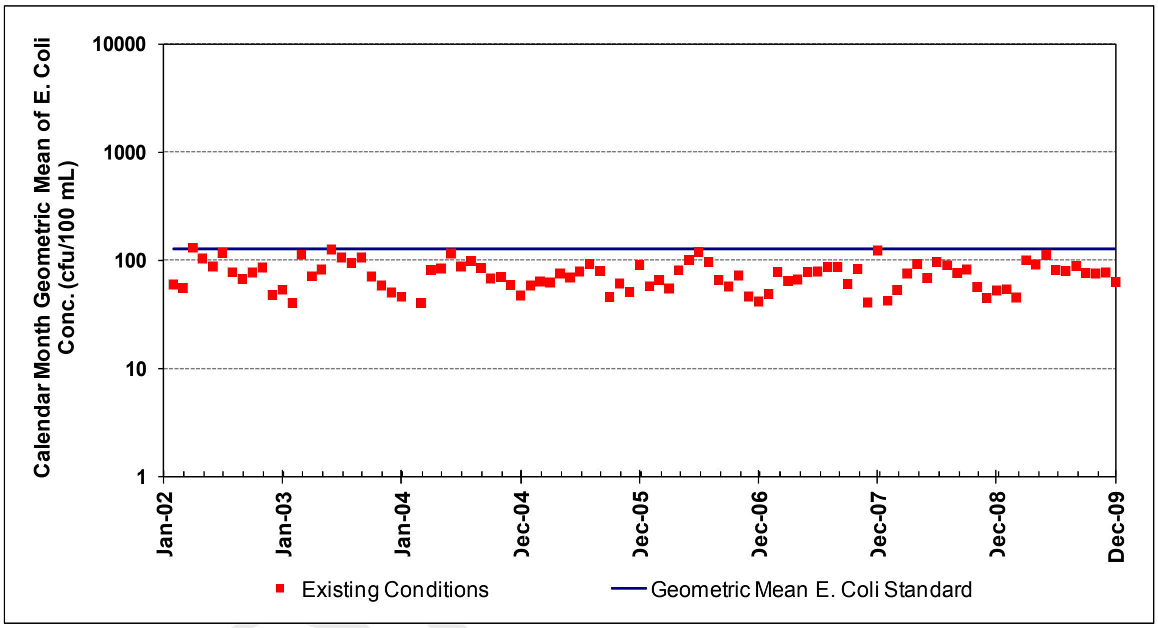

Figure 3- 29: Austin Run *E. coli* Geometric Mean Existing Conditions

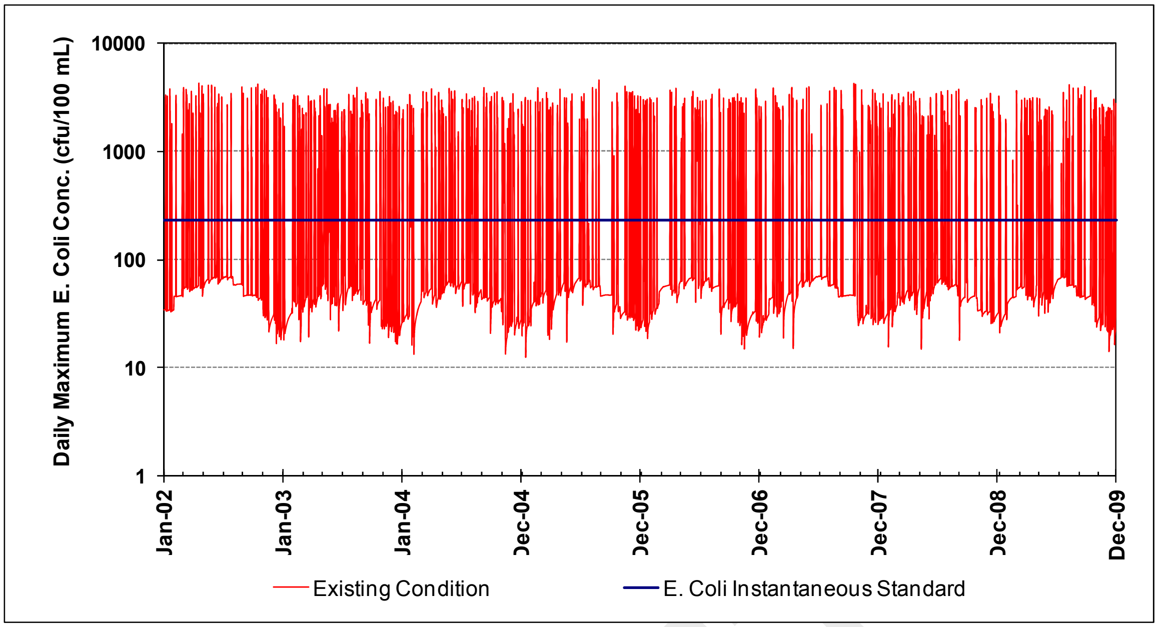

Figure 3- 30: Austin Run *E. coli* Instantaneous Existing Conditions

Table 3- 18: Austin Run (Segment VAN-A28R-AUS01A04) *E. coli* Existing Load Distribution

Source	Annual Average *E. coli* Loads	
	cfu/year	%
Forest	4.33E+13	49.5%
Cropland	7.42E+09	0.0%
Pasture	2.88E+09	0.0%
Low Density Residential	3.36E+13	38.4%
Cattle - Direct Deposition	2.48E+10	0.0%
Wildlife-Direct Deposition	1.67E+12	1.9%
Failed Septics	9.62E+11	1.1%
Point Source	7.87E+12	9.0%
Total	8.74E+13	100.0%

3.11.7 Accokeek Creek

The instream concentration of bacteria under existing conditions in the Accokeek Creek mainstem is above both the fecal coliform and E. coli geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-31** shows the E. coli geometric mean concentrations under existing conditions and **Figure 3-32** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing *E. coli* load by source in Accokeek Creek (segment VAN-A29R-ACC01A00) is presented in **Table 3-19**. E. coli concentrations in the impaired Accokeek Creek segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-19** shows that loading from residential areas (which includes the fecal coliform load from pets) as well as indirect deposition from pasture (which includes the fecal coliform load from cattle and wildlife) are the predominant sources of bacteria in the Accokeek Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets, wildlife and cattle will dominate. Under dry weather conditions, the direct deposition loads from wildlife will dominate.

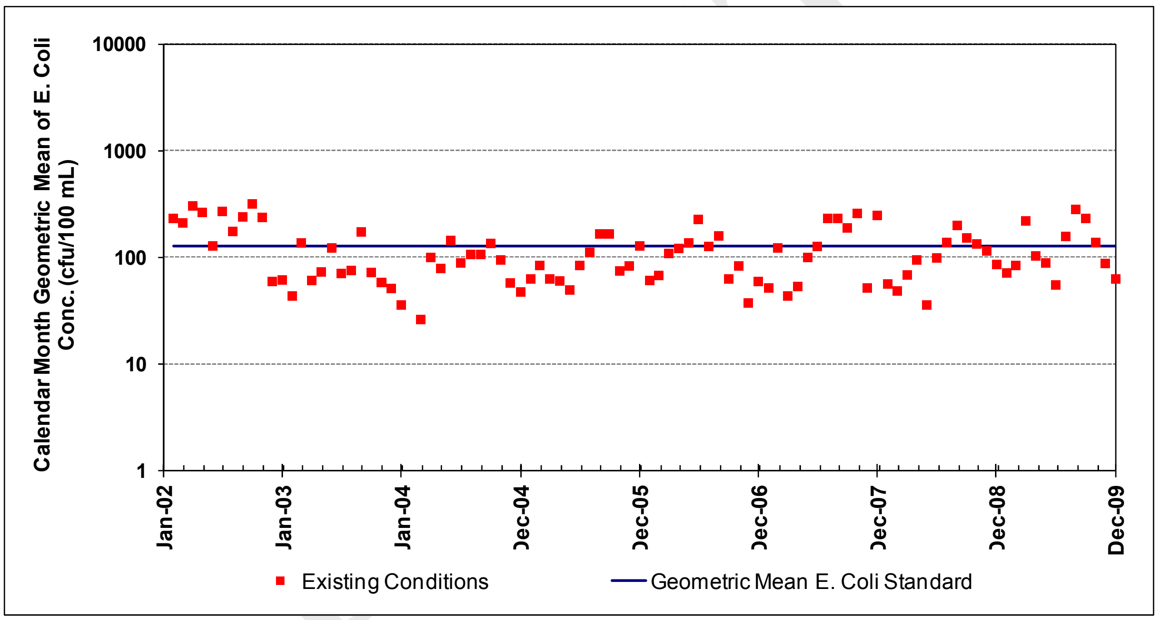

Figure 3- 31: Accokeek Creek *E. coli* Geometric Mean Existing Conditions

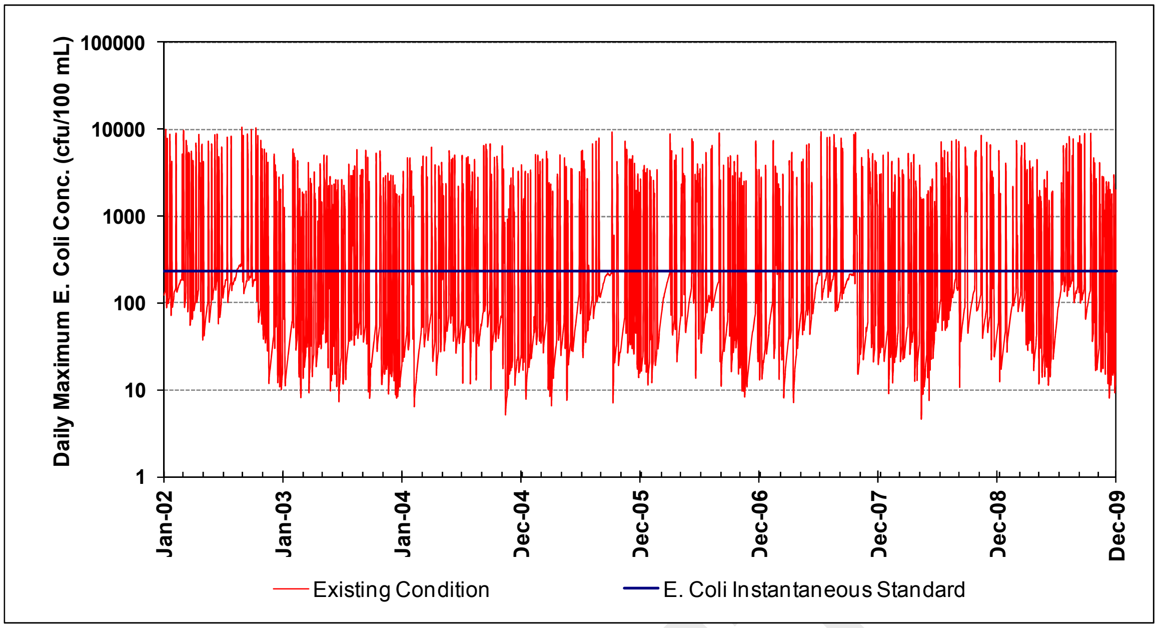

Figure 3- 32: Accokeek Creek *E. coli* Instantaneous Existing Conditions

Table 3- 19:Accokeek Creek (Segment VAN-A29R-ACC01A00) *E. coli* Existing Load Distribution

Source	Annual Average *E. coli* Loads	
	cfu/year	%
Forest	7.24E+12	11.4%
Cropland	5.52E+11	0.9%
Pasture	1.01E+13	15.9%
Urban	4.24E+13	66.7%
Cattle - Direct Deposition	1.40E+12	2.2%
Wildlife-Direct Deposition	1.73E+12	2.7%
Failed Septics	1.33E+11	0.2%
Point Source	3.13E+09	0.0%
Total	6.35E+13	100.0%

3.11.8 Potomac Creek

The instream concentration of bacteria under existing conditions in the Potomac Creek mainstem is above both the fecal coliform and E. coli geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-33** shows the E. coli geometric mean concentrations under existing conditions and **Figure 3-34** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing *E. coli* load by source in Potomac Creek (segment VAN-A29R-POM01A00) is presented in **Table 3-20**. E. coli concentrations in the impaired Potomac Creek segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-20** shows that indirect deposition from forest (which includes the fecal coliform load from wildlife) as well as loading from residential areas (which includes the fecal coliform load from pets) are the predominant sources of bacteria in Potomac Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from wildlife and pets will dominate. Under dry weather conditions, the direct deposition loads from cattle will dominate.

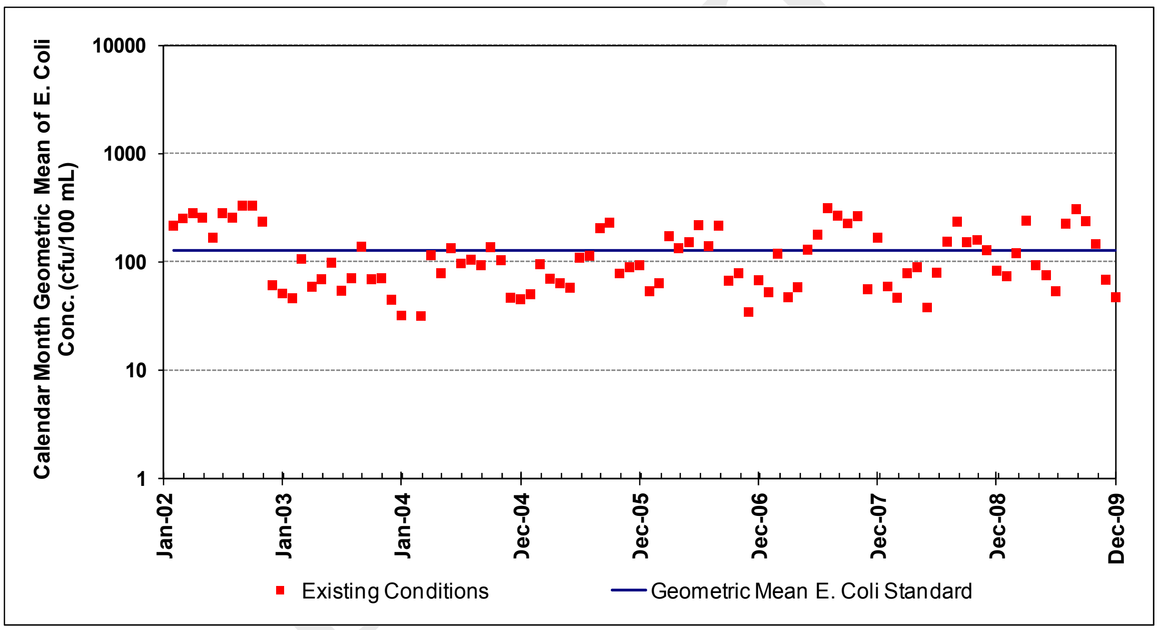

Figure 3- 33: Potomac Creek *E. coli* Geometric Mean Existing Conditions

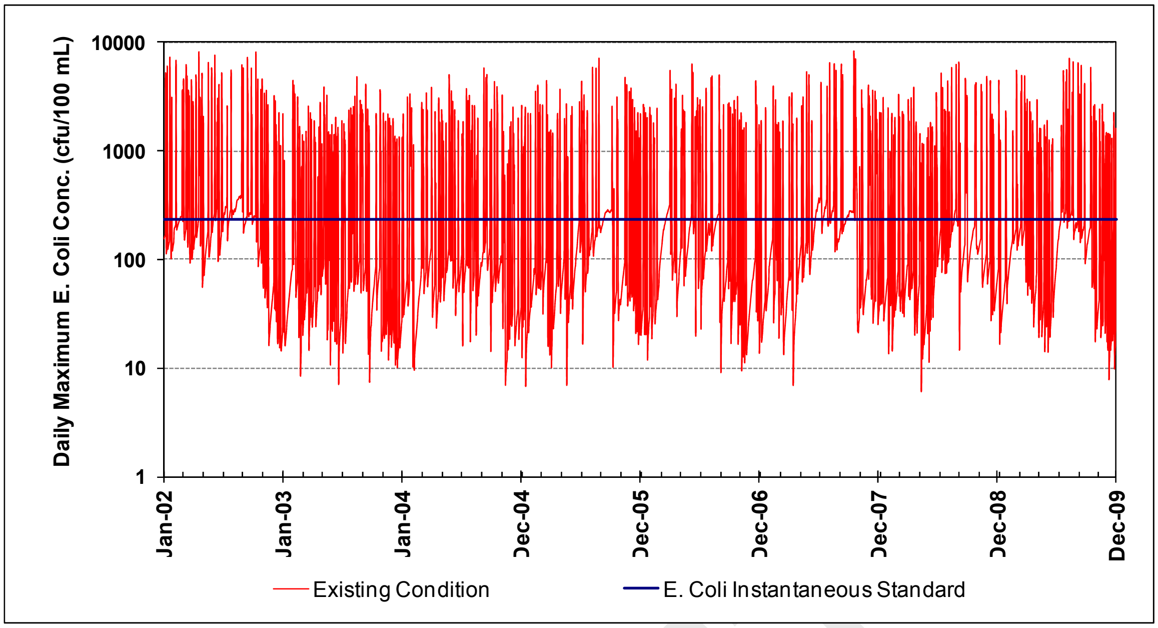

Figure 3- 34: Potomac Creek *E. coli* Instantaneous Existing Conditions

Table 3- 20: Potomac Creek (Segment VAN-A29R-POM01A00) *E. coli* Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	5.61E+13	38.4%
Cropland	7.27E+12	5.0%
Pasture	3.26E+13	22.3%
Urban	4.44E+13	30.4%
Cattle - Direct Deposition	5.37E+12	3.7%
Wildlife-Direct Deposition	1.21E+11	0.1%
Failed Septics	2.18E+11	0.1%
Point Source	0.00E+00	0.0%
Total	1.46E+14	100.0%

3.11.9 Potomac Run

The instream concentration of bacteria under existing conditions in the Potomac Run mainstem is above both the fecal coliform and E. coli geometric mean and maximum assessment criteria for the majority of the time period. **Figure 3-35** shows the E. coli geometric mean concentrations under existing conditions and **Figure 3-36** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing *E. coli* load by source in Potomac Run (segment VAN-A29R-POR01A06) is presented in **Table 3-21**. E. coli concentrations in the impaired Potomac Run segment were calculated from fecal coliform concentrations using the instream translator. **Table 3-21** shows that indirect deposition from pasture (which includes the fecal coliform load from wildlife and cattle), as well as direct loading from cattle, are the predominant sources of bacteria in Potomac Run watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from wildlife and cattle will dominate. Under dry weather conditions, the direct deposition loads from cattle will dominate.

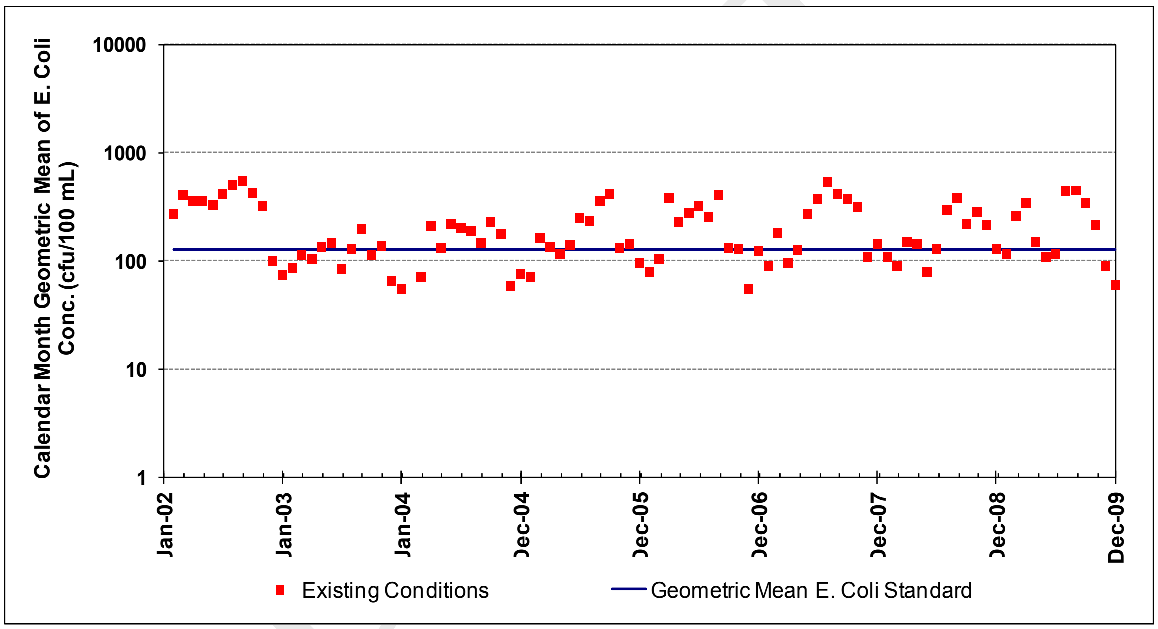

Figure 3- 35: **Potomac Run *E. coli* Geometric Mean Existing Conditions**

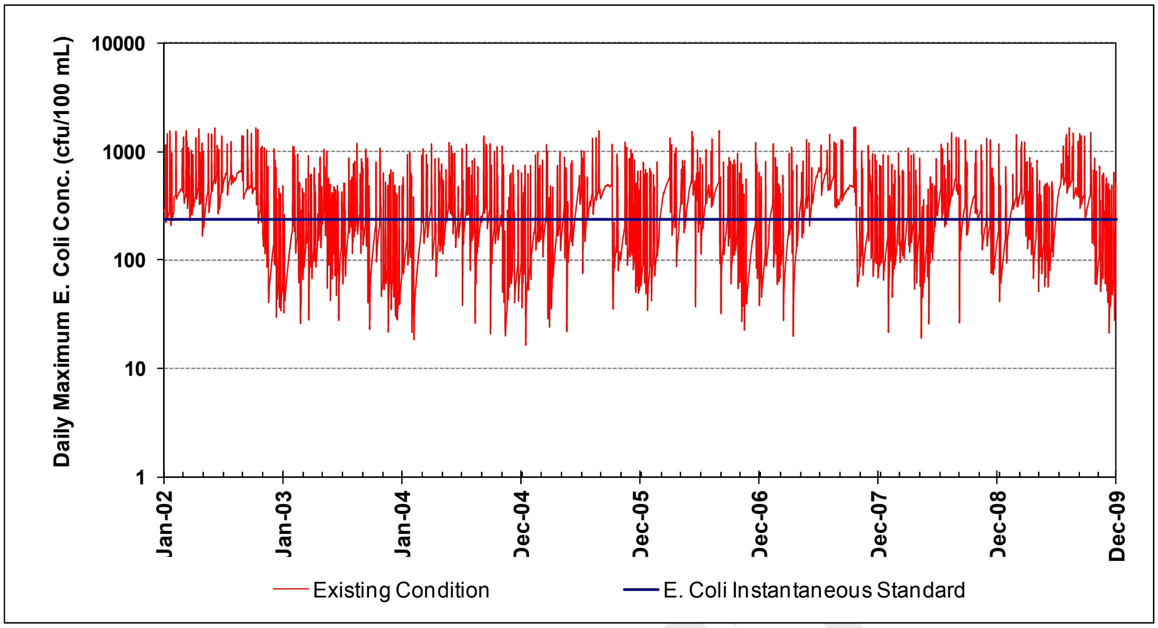

Figure 3- 36: **Potomac Run *E. coli* Instantaneous Existing Conditions**

Table 3- 21: Potomac Run (Segment VAN-A29R-POR01A06) *E. coli* Existing Load Distribution		
	Annual Average Fecal Coliform Loads	
Source	**cfu/year**	**%**
Forest	1.31E+13	16.3%
Cropland	4.14E+12	5.1%
Pasture	3.64E+13	45.2%
Urban	2.63E+12	3.3%
Cattle - Direct Deposition	2.19E+13	27.2%
Wildlife-Direct Deposition	2.17E+12	2.7%
Failed Septics	2.16E+11	0.3%
Point Source	0.00E+00	0.0%
Total	8.05E+13	100.0%

4.0 Allocation

Allocation analysis was the third stage in the development of the Tributaries to the Potomac River: Prince William and Stafford Counties Bacteria TMDLs. The purpose of this third stage was to develop the framework for reducing bacteria loading under the existing watershed conditions so that water quality standards may be met. The TMDLs represents the maximum amount of pollutant that the stream can receive without exceeding the water quality criteria. The load allocations for the selected scenarios were calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = waste load allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

Typically, several potential allocation strategies would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

4.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using one of two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations.

- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly geometric mean criterion of 126 cfu/100 mL for *E. coli* bacteria. In addition, it is required that final allocation scenarios be designed so that there is no more than a 10% exceedance rate of the maximum assessment criterion for *E. coli* of 235 cfu/100 mL.

4.2 Allocation Scenario Development

Allocation scenarios were modeled using the calibrated HSPF model to adjust the existing conditions until the water quality criteria were attained. The Tributaries to the Potomac River: Prince William and Stafford Counties TMDLs were based on the Virginia water quality criteria for *E. coli*. As detailed in Section 1.3, the *E. coli* criterion states that the calendar-month geometric mean concentration shall not exceed 126 cfu/100 mL, and that a maximum single sample concentration of *E. coli* shall not exceed 235 cfu/100 mL more than 10 percent of the time. According to the guidelines put forth by the VADEQ (VADEQ, 2011) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, and then the model output was converted to concentrations of *E. coli* with the following equation:

$$\log_2 EC\ (cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC\ (cfu/100mL)$$

Where: EC = E. coli bacteria concentration
FC = Fecal coliform bacteria concentration

The pollutant concentrations were simulated over the entire duration of a representative modeling period, and pollutant loads were adjusted until the criteria was met. The pollutant loads were calculated at the outlet of the impaired segments. The development of the allocation scenarios was an iterative process requiring numerous runs where each run was followed by an assessment of source reduction against the water quality target. The long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the following equation (*USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*):

$$MDL = LTA \times Exp[z\sigma - 0.5\sigma^2] \quad \text{Where;}$$

MDL = maximum daily limit (cfu/day)

LTA = long-term average (cfu/day)

z = z statistic of the probability of occurrence

$\sigma^2 = \ln(CV^2+1)$

CV = coefficient of variation

Daily expressions for aggregate WLAs and LAs were calculated using the above method. The daily expression of individual WLAs, presented in Tables 4-1 through 4-4, were calculated based on the average annual individual WLAs divided by 365 days in a year. These daily average values are not intended to represent maximum allowable daily loads. Rather, they represent the average daily loadings that may be expected to occur over the long term.

The following sections present the waste load allocation (WLA) and load allocations (LA) for the impaired segment.

4.3 Wasteload Allocation

This section outlines the wasteload allocations (WLA) for the impaired segments. It presents the existing and allocated loads for each permitted (VPDES and MS4) facility contributing to the impaired segments.

4.3.1 Powells Creek

There are no municipal VPDES permitted facilities which discharge into the Powells Creek bacteria impaired watershed. However, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. The future growth allocation for VPDES point sources in the Powells Creek watershed is 7.63E+10 cfu/year.

4.3.2 Quantico Creek

There are no municipal VPDES permitted facilities which discharge into the Quantico Creek bacteria impaired watershed. However, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. The future growth allocation for VPDES point sources in the Quantico Creek watershed is 1.14E+11 cfu/year.

4.3.3 South Fork Quantico Creek

There are no municipal VPDES permitted facilities which discharge into the South Fork Quantico Creek bacteria impaired watershed. However, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. The future growth allocation for VPDES point sources in the South Fork Quantico Creek watershed is 2.80E+10 cfu/year.

4.3.4 North Branch Chopawamsic Creek

There are no municipal VPDES permitted facilities which discharge into the North Branch Chopawamsic Creek bacteria impaired watershed. However, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. The future growth allocation for VPDES point sources in the North Branch Chopawamsic Creek watershed is 3.86E+10 cfu/year.

4.3.5 Unnamed Tributary to Potomac River

There is one VPDES permitted facility which discharges into the Unnamed Tributary to Potomac River bacteria impaired watershed (Permit VAG406114). It has been assigned a waste load allocation equal to its maximum permitted design flow (0.001 MGD) multiplied by the geometric mean *E. coli* criterion of 126 CFU/100mL and the appropriate conversion factors, resulting in a allocation of 1.74E+09 CFU/year. In addition, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. The TMDL allocation plan for the VPDES permit in the Unnamed Tributary to Potomac River is presented in **Table 4-1**.

Table 4- 1: WLA for VPDES Permitted Facilities in the Unnamed Tributary to Potomac River Watershed

Permit Number	Facility Type	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/day)	Wasteload Allocation (cfu/year)
VAG406114	Residence	0.001	126	4.77E+06	1.74E+09
Future Growth Allocation for VPDES Point Sources:				3.29E+07	1.20E+10
Total WLA for VPDES Point Sources				**3.76E+07**	**1.37E+10**

4.3.6 Austin Run

There are two VPDES permitted facilities which discharge into the Austin Run bacteria impaired watershed (Individual, VPDES Municipal Permits VA0092479 and VA0060968). Each has been assigned a waste load allocation equal to its maximum design flow multiplied by the geometric mean *E. coli* criterion of 126 CFU/100mL and the appropriate conversion factors, resulting in a combined allocation of 2.09E+13 CFU/year. In addition, an additional allocation equivalent to 6 MGD at the water quality geometric mean criterion for *E. coli* (126 CFU/100mL) was included to accommodate future growth and expansion of point sources in the watershed. TMDL allocations for the VPDES permits in Austin Run are presented in **Table 4-2**.

Table 4- 2: WLA for VPDES Permitted Facilities in the Austin Run Watershed

Permit Number	Facility Type	Maximum Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/day)	Wasteload Allocation (cfu/year)
VA0092479	Abrahms Ct STP	0.0036*	126	1.72E+07	6.27E+09
VA0060968	Aquia Wastewater Treatment Plant	12	126	5.73E+10	2.09E+13
Future Growth Allocation[#]		6	126	2.85E+10	1.04E+13
Total WLA for VPDES Point Sources				**8.58E+10**	**3.13E+13**

*This permit is still in draft form and has not been officially issued.
The future growth allocation was modeled as though it were coming from the Aquia WWTP; however, the future growth will be allocated to any permitted facility (either current or future) in the watershed based on the discretion of the VPDES permit and TMDL staff.

4.3.7 Accokeek Creek

There are two VPDES permitted facilities which discharge into the Accokeek Creek bacteria impaired watershed (Permits VA0089630 and VAG406279). Each has been assigned a waste load allocation equal to its maximum permitted design flow multiplied by the geometric mean *E. coli* criterion of 126 CFU/100mL and the appropriate conversion factors, resulting in a allocation of 3.13E+09 CFU/year. In addition, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. TMDL allocation plan for the VPDES permit in Accokeek Creek is presented in **Table 4-3**.

Table 4- 3: WLA for VPDES Permitted Facilities in the Accokeek Creek Watershed					
Permit Number	Facility Type	Design Flow (MGD)	Effluent Limit (cfu/100ml)	Wasteload Allocation (cfu/day)	Wasteload Allocation (cfu/year)
VA0089630	Randall STP	0.0008	126	3.81E+06	1.39E+09
VAG406207	Residence	0.001	126	4.77E+06	1.74E+09
Future Growth Allocation for VPDES Point Sources:				1.81E+08	6.62E+10
Total WLA for VPDES Point Sources				1.90E+08	6.93E+10

4.3.8 Potomac Creek

There are no municipal VPDES permitted facilities which discharge into the Potomac Creek bacteria impaired watershed. However, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. The future growth allocation for VPDES point sources in the Potomac Creek watershed is 1.12E+11 cfu/year.

4.3.9 Potomac Run

There are no municipal VPDES permitted facilities which discharge into the Potomac Run bacteria impaired watershed. However, an explicit allocation (equivalent to 1% of the total TMDL load for the watershed) was provided for the future growth of VPDES permitted point sources in the watershed. The future growth allocation for VPDES point sources in the Potomac Run watershed is 2.03E+10 cfu/year.

4.3.10 MS4 Allocations

As discussed in the earlier section, loads associated with MS4 areas are considered part of the wasteload allocation. Seven MS4 permits have been issued in the Tributaries to the Potomac River: Prince William and Stafford Counties Bacteria TMDL watersheds. To separate bacteria loadings attributed to the MS4s from other land-based bacteria loading, an area weighted method was used. In the case of Phase I Municipalities, all land-based loadings from developed land use categories (i.e. high, medium, and low intensity developed land uses) within the permit boundaries were allocated to the MS4s. In the case of Phase II MS4 Permits, all land-based loadings from developed land use categories within the Census-defined urban areas of the permit boundaries were allocated to the MS4s.

One disadvantage to this approach is that it is not able to distinguish between urban areas that drain to MS4s and those that drain to pervious areas, allowing infiltration into subsurface flows, or directly to surface waters. However, at the time of TMDL development, detailed information regarding the portion of watershed that drains to each MS4 system was not available, so a conservative, land-use based approach was used. The WLAs for MS4 permittees can be revised in the future, as necessary, if additional information regarding the MS4 drainage areas becomes available.

Due to the spatial overlap between MS4 entities and the resulting uncertainty of the appropriate operator of the system, the MS4 loads are aggregated by jurisdiction (Prince William County, Stafford County, and Town of Dumfries) in the TMDL. In most cases, the boundaries of MS4 areas are not available in enough geospatial detail to disaggregate the MS4 loads and assign individual Waste Load Allocations. EPA, DEQ, and DCR support the aggregation of MS4 WLAs for this reason. Additionally, aggregation encourages stakeholder cooperation and speeds the implementation of appropriate BMPs to address reductions required by the TMDL.

Table 4-4 lists the wasteload allocations associated with each MS4 jurisdiction, as well as their designation as Phase I or Phase II municipalities. The allocated *E. coli* load from MS4 sources in the Powells Creek watershed is 2.30E+12 cfu/year; 1.22E+12 cfu/year in Quantico Creek/South Fork Quantico Creek; 3.54E+10 cfu/year in North Branch Chopawamsic Creek; 2.08E+11 cfu/year in Unnamed Tributary to Potomac River; 9.03E+11 cfu/year in Austin Run; 1.39E+11 cfu/year in Accokeek Creek; and 1.05E+11 cfu/year in Potomac Creek/Potomac Run. (**Table 4-4**).

Table 4- 4: MS4 Wasteload Allocation for *E. coli*

Permit Number	MS4 Permit	MS4 Geographical Area	Developed Acres	Overall MS4 Allocation (cfu/year)	MS4 Allocation by Jurisdiction (cfu/day)	MS4 Allocation by Jurisdiction (cfu/year)
Powells Creek (A26R-02-BAC)						
VA0088595	Prince William County	Prince William County	2,242	2.30E+12	6.30E+09	2.30E+12
VAR040100	Prince William County Public Schools					
VAR040115	Virginia Department of Transportation					
		Total MS4 WLA	2,242	2.30E+12	6.30E+09	2.30E+12
Quantico Creek (A26R-03-BAC) & South Fork Quantico Creek (A26R-05-BAC)						
VA0088595	Prince William County	Prince William County	577.1	1.22E+12	2.30E+09	8.41E+11
VAR040100	Prince William County Public Schools					
VAR040115	Virginia Department of Transportation					
VAR040117	Town of Dumfries	Town of Dumfries	259.9		1.04E+09	3.79E+11
VAR040115	Virginia Department of Transportation					
		Total MS4 WLA	837	1.22E+12	3.34E+09	1.22E+12
North Branch Chopawamsic Creek (A26R-04-BAC)						
VA0088595	Prince William County	Prince William County	5.6	3.54E+10	9.70E+07	3.54E+10
VAR040100	Prince William County Public Schools					
VAR040115	Virginia Department of Transportation					
VAR040069	United States Marine Corps, Quantico					
		Total MS4 WLA	5.6	3.54E+10	9.70E+07	3.54E+10
Unnamed Tributary to Potomac River (A26R-07-BAC)						
VAR040056	Stafford County	Stafford County	121	2.08E+11	5.70E+08	2.08E+11
VAR040071	Stafford County Public Schools					
VAR040115	Virginia Department of Transportation					
		Total MS4 WLA	121	2.08E+11	5.70E+08	2.08E+11
Austin Run (A28R-01-BAC)						
VAR040056	Stafford County	Stafford County	1537.3	9.03E+11	2.47E+09	9.03E+11
VAR040071	Stafford County Public Schools					
VAR040115	Virginia Department of Transportation					
		Total MS4 WLA	1537.3	9.03E+11	2.47E+09	9.03E+11

Table 4- 4: MS4 Wasteload Allocation for *E. coli*

Permit Number	MS4 Permit	MS4 Geographical Area	Developed Acres	Overall MS4 Allocation (cfu/year)	MS4 Allocation by Jurisdiction (cfu/day)	MS4 Allocation by Jurisdiction (cfu/year)
Accokeek Creek (A29R-01-BAC)						
VAR040056	Stafford County	Stafford County	57.6	1.39E+11	3.81E+08	1.39E+11
VAR040071	Stafford County Public Schools					
VAR040115	Virginia Department of Transportation					
	Total MS4 WLA		57.6	1.39E+11	3.81E+08	1.39E+11
Potomac Creek (A29R-02-BAC) & Potomac Run (A29R-03-BAC)						
VAR040056	Stafford County	Stafford County	29.8	1.05E+11	2.88E+08	1.05E+11
VAR040115	Virginia Department of Transportation					
	Total MS4 WLA		29.8	1.05E+11	2.88E+08	1.05E+11

4.4 Load Allocation Development

The reduction of loadings from non-point sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed in order to determine the final TMDL load allocation. Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the HSPF model for the hydrologic period of January 2006 to December 2010. The following is a list of load allocation scenarios that were implemented to arrive at the final TMDL allocations. Additional scenarios deemed necessary were also implemented to attain the final TMDL. The following is a brief summary of the key scenarios:

- Scenario 0 is the existing load, no reduction of any of the sources.
- Scenario 1 represents elimination of human sources (failing sewage disposal systems).
- Scenario 2 represents the elimination of human sources (failing sewage disposal systems) as well as half the direct instream loading from livestock.
- Scenario 3 represents the elimination of the human sources (failing sewage disposal systems) as well as the direct instream loading from livestock.

- Scenario 4 represents the elimination of all non-point sources and direct instream loading from livestock.
- Scenario 5 represents the elimination of the human sources (failing sewage disposal systems) and direct instream loading from livestock as well as half of the direct wildlife contribution.
- Scenario 6 represents the elimination of the human sources (failing sewage disposal systems) and direct instream loading from livestock as well as 75% of the direct wildlife contribution.
- Scenario 7 represents the elimination of the human sources (failing sewage disposal systems), direct instream loading from livestock, 95% of the loading from agricultural nonpoint sources, 95% of the loading from urban non-point sources, and 75% of the wildlife contribution.
- Scenario 8 represents the elimination of the human sources (failing sewage disposal systems), direct instream loading from livestock, 85% of the loading from agricultural nonpoint sources, 85% of the loading from urban non-point sources, and 80% of the wildlife contribution.

Additional scenarios were necessary in order to reach the assigned endpoints. The following section discusses the scenario implementation for each TMDL.

4.4.1 Powells Creek

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, 98 percent reduction of agricultural and urban non-point sources, and an 84.4 percent reduction of indirect wildlife deposition are required.

Table 4- 5: Powells Creek Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the E. Coli Geometric Mean Criterion	Percent Exceedance of the E. Coli Maximum Assessment Criterion
0							55%	32%
1	100						55%	32%
2	100	50					46%	31%
3	100	100					30%	31%
4	100	100	100	100	100		0%	0%
5	100	100				50	15%	31%
6	100	100				75	4%	31%
7	100	100	95	95	95		1%	17%
8	100	100	85	85	85		7%	23%
9	100	100	90	90	90		3%	21%
10	100	50	50	50	50		32%	28%
11	100	75	75	75	75		18%	26%
12	100	100				100	0%	31%
13	**100**	**100**	**98.0**	**98.0**	**84.4**	**0**	**0%**	**10%**

4.4.2 Quantico Creek

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition and 98.6 percent reduction of agricultural and urban nonpoint sources are required.

Table 4- 6: Quantico Creek Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the *E. Coli* Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							18%	27%
1	100						18%	27%
2	100	50					17%	27%
3	100	100					16%	27%
4	100	100	100	100	100		0%	1%
5	100	100				50	0%	26%
6	100	100				75	0%	26%
7	100	100	95	95	95		0%	11%
8	100	100	85	85	85	0	1%	19%
9	100	100	90	90	90	0	0%	17%
10	100	50	50	50	50	0	9%	25%
11	100	75	75	75	75	0	1%	22%
12	100	100				100	0%	26%
13	**100**	**100**	**98.6**	**98.6**	**0**	**0**	**0%**	**9%**

4.4.3 South Fork Quantico Creek

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, a 95 percent reduction of agricultural and urban nonpoint sources, and a 76 percent reduction of indirect wildlife deposition are required.

Table 4- 7: South Fork Quantico Creek Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the *E. Coli* Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							13%	22%
1	100						13%	22%
2	100	50					12%	22%
3	100	100					12%	22%
4	100	100	100	100			3%	16%
5	100	100				50	1%	23%
6	100	100				75	1%	23%
7	100	100	95	95	95		0%	2%
8	100	100	85	85	85	0	0%	6%
9	100	100	90	90	90	0	0%	3%
10	100	50	50	50	50	0	2%	13%
11	100	75	75	75	75	0	0%	12%
12	100	100				100	0%	18%
13	**100**	**100**	**95**	**95**	**76**	**0**	**0%**	**10%**

4.4.4 North Branch Chopawamsic Creek

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, 93.6 percent reduction of agricultural and urban non-point sources, and a 93.6 percent reduction of indirect wildlife deposition are required.

Table 4- 8: North Branch Chopawamsic Creek Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the E. Coli Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							25%	29%
1	100						25%	29%
2	100	50					25%	29%
3	100	100					25%	29%
4	100	100	100	100			23%	27%
5	100	100				50	4%	27%
6	100	100				75	1%	27%
7	100	100	95	95	95	0	0%	9%
8	100	100	85	85	85	0	2%	12%
9	100	100	90	90	90	0	0%	12%
10	100	50	50	50	50	0	6%	17%
11	100	75	75	75	75	0	4%	15%
12	100	100				100	0%	19%
13	**100**	**100**	**93.6**	**93.6**	**93.6**	**0**	**0%**	**10%**

4.4.5 Unnamed Tributary to Potomac River

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, 94.4 percent reduction of agricultural and urban non-point sources, and a 94.4 percent reduction of indirect wildlife deposition are required.

Table 4- 9: Unnamed Tributary to Potomac River Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the *E. Coli* Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							19%	25%
1	100						18%	24%
2	100	50					18%	24%
3	100	100					16%	24%
4	100	100	100	100			6%	17%
5	100	100				50	0%	21%
6	100	100				75	0%	20%
7	100	100	95	95	95	0	0%	9%
8	100	100	85	85	85	0	0%	13%
9	100	100	90	90	90	0	0%	12%
10	100	50	50	50	50	0	3%	19%
11	100	75	75	75	75	0	1%	17%
12	100	100				100	0%	19%
13	**100**	**100**	**94.4**	**94.4**	**94.4**	**0**	**0%**	**10%**

4.4.6 Austin Run

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 12. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, 95.9 percent reduction of agricultural and urban nonpoint sources, and a 95.9 percent reduction of indirect wildlife deposition are required.

Table 4- 10: Austin Run Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the *E. Coli* Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							98%	25%
1	100						98%	25%
2	100	50					98%	25%
3	100	100					98%	25%
4	100	100	100	100			10%	19%
5	100	100				50	65%	24%
6	100	100				75	61%	24%
7	100	100	85	85	85	0	8%	19%
8	100	100	90	90	90	0	7%	17%
9	100	50	50	50	50	0	12%	21%
10	100	75	75	75	75	0	10%	22%
11	100	100	95	95	95	0	0%	11%
12	**100**	**100**	**95.9**	**95.9**	**95.9**	**0**	**0%**	**10%**

4.4.7 Accokeek Creek

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, 95.5 percent reduction of agricultural and urban nonpoint sources, and a 65.5 percent reduction of indirect wildlife deposition are required.

Table 4- 11: Accokeek Creek Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the *E. Coli* Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							38%	31%
1	100						33%	31%
2	100	50					25%	30%
3	100	100					18%	30%
4	100	100	100	100			1%	23%
5	100	100				50	4%	21%
6	100	100				75	2%	21%
7	100	100	95	95	95	0	0%	11%
8	100	100	85	85	85	0	1%	15%
9	100	100	90	90	90	0	1%	13%
10	100	50	50	50	50	0	17%	22%
11	100	75	75	75	75	0	7%	19%
12	100	100				100	0%	18%
13	**100**	**100**	**95.5**	**95.5**	**65.5**	**0**	**0%**	**10%**

4.4.8 Potomac Creek

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, 92.2 percent reduction of agricultural and urban nonpoint sources, and a 92.2 percent reduction of indirect wildlife deposition are required.

Table 4- 12: Potomac Creek Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the E. Coli Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							32%	34%
1	100						32%	34%
2	100	50					28%	32%
3	100	100					17%	29%
4	100	100	100	100			5%	14%
5	100	100				50	5%	27%
6	100	100				75	5%	27%
7	100	100	95	95	95	0	0%	4%
8	100	100	85	85	85	0	0%	16%
9	100	100	90	90	90	0	0%	12%
10	100	50	50	50	50	0	15%	25%
11	100	75	75	75	75	0	5%	19%
12	100	100				100	4%	27%
13	**100**	**100**	**92.2**	**92.2**	**92.2**	**0**	**0%**	**10%**

4.4.9 Potomac Run

The TMDL load allocation scenario that resulted in no exceedances of the *E. coli* geometric mean criterion and not more than 10% exceedance of the maximum assessment criterion was Scenario 13. Under this scenario, complete elimination of the human sources (failing sewage disposal systems) and livestock direct deposition, 98 percent reduction of agricultural, wildlife indirect deposition, and urban nonpoint sources is required, as well as a 59 percent reduction of direct wildlife deposition.

Table 4- 13: Potomac Run Load Reductions Under 30-Day Geometric Mean and Maximum Assessment Criteria for *E. coli*

Scenario	Failing Sewage Disposal Systems	Direct Deposition from Cattle	Non-Point Source Agriculture	Non-Point Source Urban	Non-Point Source Forest (Wildlife)	Direct Deposition from Wildlife	Percent Exceedance of the E. Coli Geometric Mean Criterion	Percent Exceedance of the *E. Coli* Maximum Assessment Criterion
0							100%	85%
1	100						100%	85%
2	100	50					97%	77%
3	100	100					15%	34%
4	100	100	100	100			7%	20%
5	100	100				50	2%	25%
6	100	100				75	0%	25%
7	100	100	95	95	95	0	5%	18%
8	100	100	85	85	85	0	7%	21%
9	100	100	90	90	90	0	8%	21%
10	100	50	50	50	50	0	36%	43%
11	100	75	75	75	75	0	22%	34%
12	100	100				100	0%	24%
13	**100**	**100**	**98.0**	**98.0**	**98.0**	**59.0**	**0%**	**10%**

4.5 Powells Creek Allocation Plan and TMDL Summary

As shown in **Table 4-5**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100 ml for Powells Creek. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban nonpoint sources.

- 84.4 percent reduction of the indirect loading from wildlife.

Table 4-14 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 14: Powells Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	1.49E+13	2.33E+12	84.4%
Cropland	1.44E+12	2.88E+10	98.0%
Pasture	1.36E+13	2.72E+11	98.0%
Urban(1)	1.15E+14	2.30E+12	98.0%
Cattle-Direct Deposition	2.09E+12	0.00E+00	100.0%
Wildlife-Direct Deposition	2.62E+12	2.62E+12	0.0%
Failing Sewage Disposal Systems	4.04E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	7.55E+10	-
Total	**1.50E+14**	**7.63E+12**	**94.9%**

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for Powells Creek is presented in **Table 4-15.**

Table 4- 15: Powells Creek TMDL (cfu/year) for *E. coli*

Watershed	WLA[1]	LA	MOS	TMDL
Powells Creek	**2.38E+12**	**5.25E+12**	**IMPLICIT**	**7.63E+12**

[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for Powells Creek is presented in **Table 4-16**.

Table 4- 16: Powells Creek TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Powells Creek	**2.07E+08**	**7.58E+10**	**IMPLICIT**	**7.60E+10**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

The resulting geometric mean and maximum assessment criteria for *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-1** and **Figure 4-2**. **Figure 4-1** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-2** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For Powells Creek, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

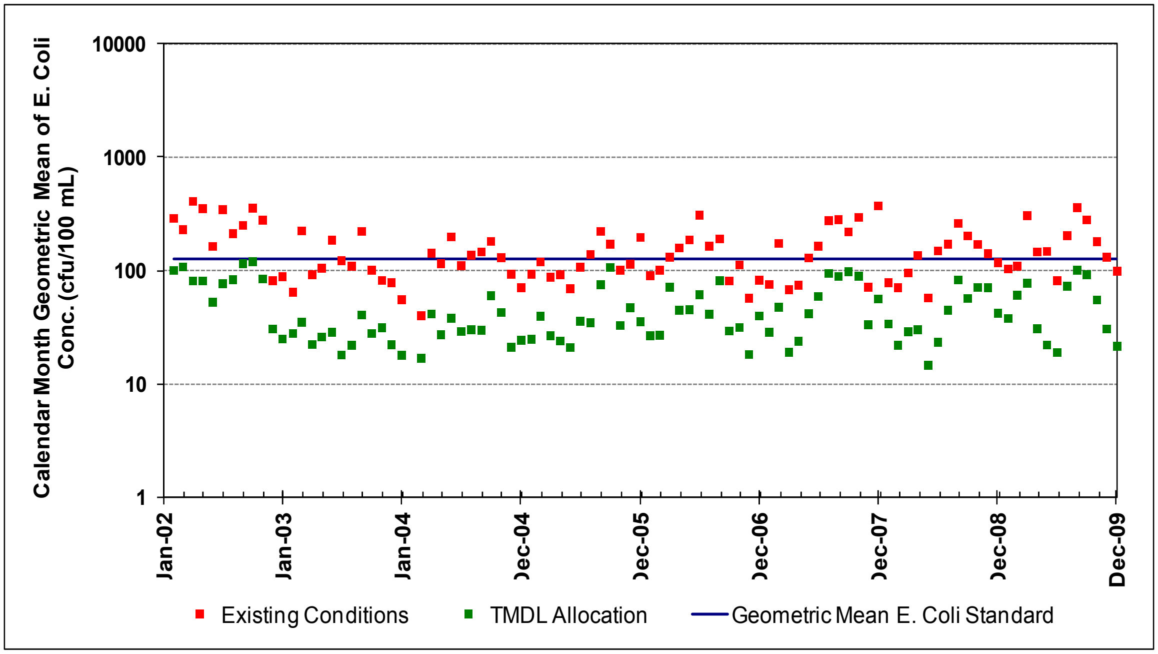

Figure 4- 1: Powells Creek Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

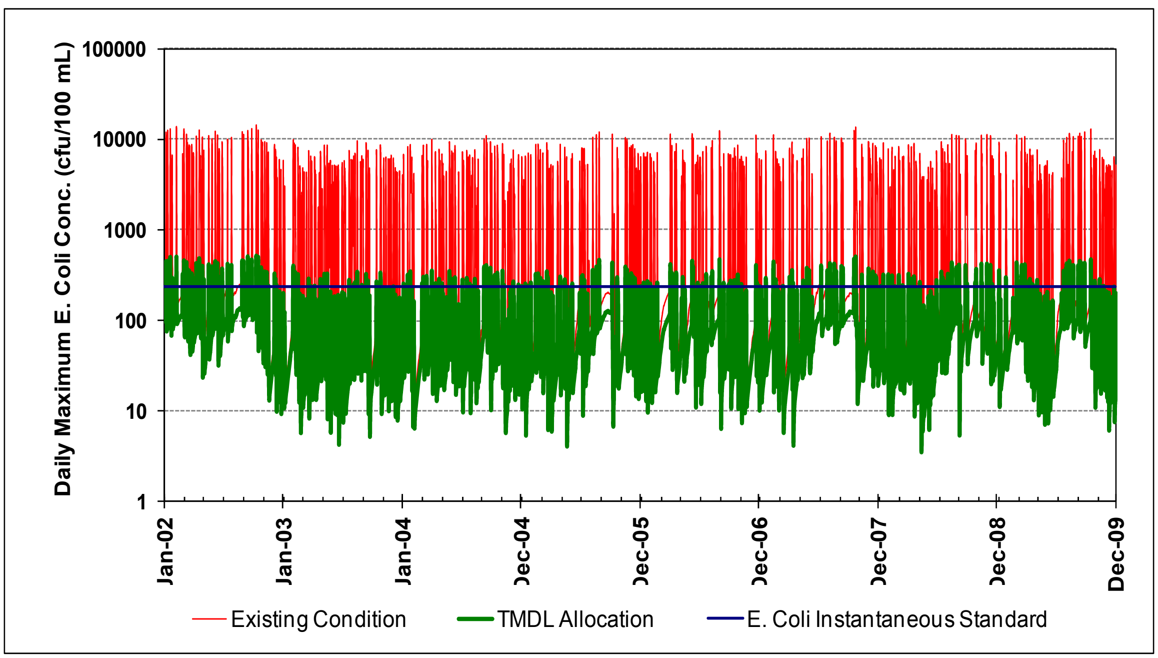

Figure 4- 2: Powells Creek Instantaneous *E. coli* Concentrations under Allocation Scenario 13

4.6 Quantico Creek Allocation Plan and TMDL Summary

As shown in **Table 4-6**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100ml for Quantico Creek. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 98.6 percent reduction of bacteria loading from agricultural and urban nonpoint sources.

Table 4-17 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 17: Quantico Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	7.59E+12	7.59E+12	0.00%
Cropland	6.88E+10	9.64E+08	98.6%
Pasture	4.21E+10	5.89E+08	98.6%
Urban(1)	8.64E+13	1.21E+12	98.6%
Cattle-Direct Deposition	2.34E+10	0.00E+00	100.0%
Wildlife-Direct Deposition	2.47E+12	2.47E+12	0.0%
Failing Sewage Disposal Systems	1.37E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	1.13E+11	-
Total	**9.67E+13**	**1.14E+13**	**88.2%**

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for Quantico Creek is presented in **Table 4-18.**

Table 4- 18: Quantico Creek TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Quantico Creek	**1.32E+12**	**1.01E+13**	**IMPLICIT**	**1.14E+13**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for Quantico Creek is presented in **Table 4-19**.

Table 4- 19: Quantico Creek TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Quantico Creek	**3.09E+08**	**1.13E+11**	**IMPLICIT**	**1.14E+11**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-3** and **Figure 4-4**. **Figure 4-3** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-4** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For Quantico Creek, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

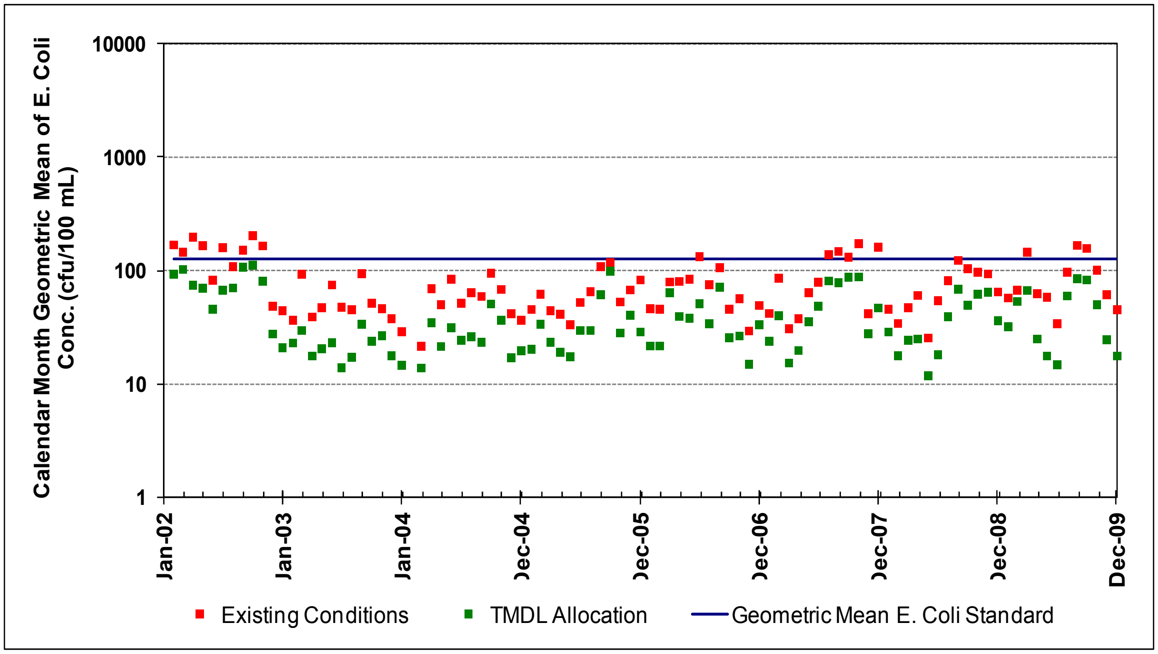

Figure 4- 3: Quantico Creek Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

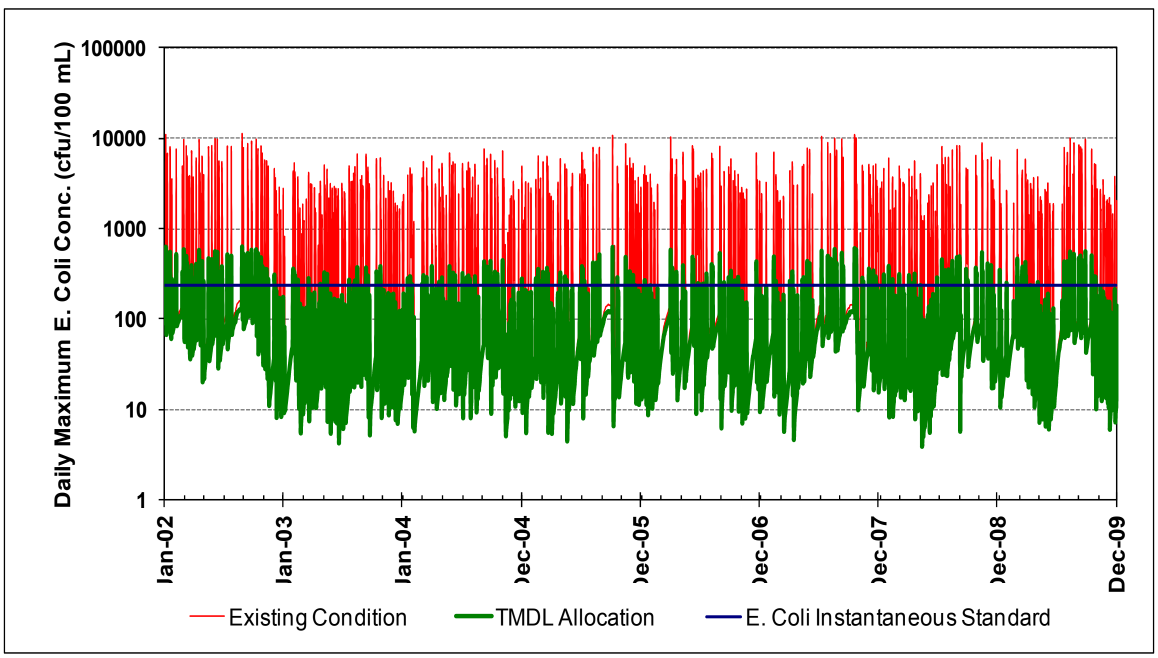

Figure 4- 4: Quantico Creek Instantaneous *E. coli* Concentrations under Allocation Scenario 13

4.7 South Fork Quantico Creek Allocation Plan and TMDL Summary

As shown in **Table 4-7**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100 ml for South Fork Quantico Creek. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 95 percent reduction of bacteria loading from agricultural and urban nonpoint sources.
- 76 percent reduction of the indirect loading from wildlife.

Table 4-20 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 20: South Fork Quantico Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	6.09E+12	1.46E+12	76.0%
Cropland	1.78E+09	8.92E+07	95.0%
Pasture	3.94E+08	1.97E+07	95.0%
Urban(1)	1.83E+11	9.15E+09	95.0%
Cattle-Direct Deposition	2.37E+11	0.00E+00	100.0%
Wildlife-Direct Deposition	1.30E+12	1.30E+12	0.0%
Failing Sewage Disposal Systems	5.52E+09	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	2.77E+10	-
Total	**7.82E+12**	**2.80E+12**	**64.2%**

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for South Fork Quantico Creek is presented in **Table 4-21.**

Table 4- 21: South Fork Quantico Creek TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
South Fork Quantico Creek	**3.69E+10**	**2.76E+12**	**IMPLICIT**	**2.80E+12**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for South Fork Quantico Creek is presented in **Table 4-22**.

Table 4- 22: South Fork Quantico Creek TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
South Fork Quantico Creek	**7.59E+07**	**2.78E+10**	**IMPLICIT**	**2.79E+10**
[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).				

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-5** and **Figure 4-6**. **Figure 4-5** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-6** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For South Fork Quantico Creek, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

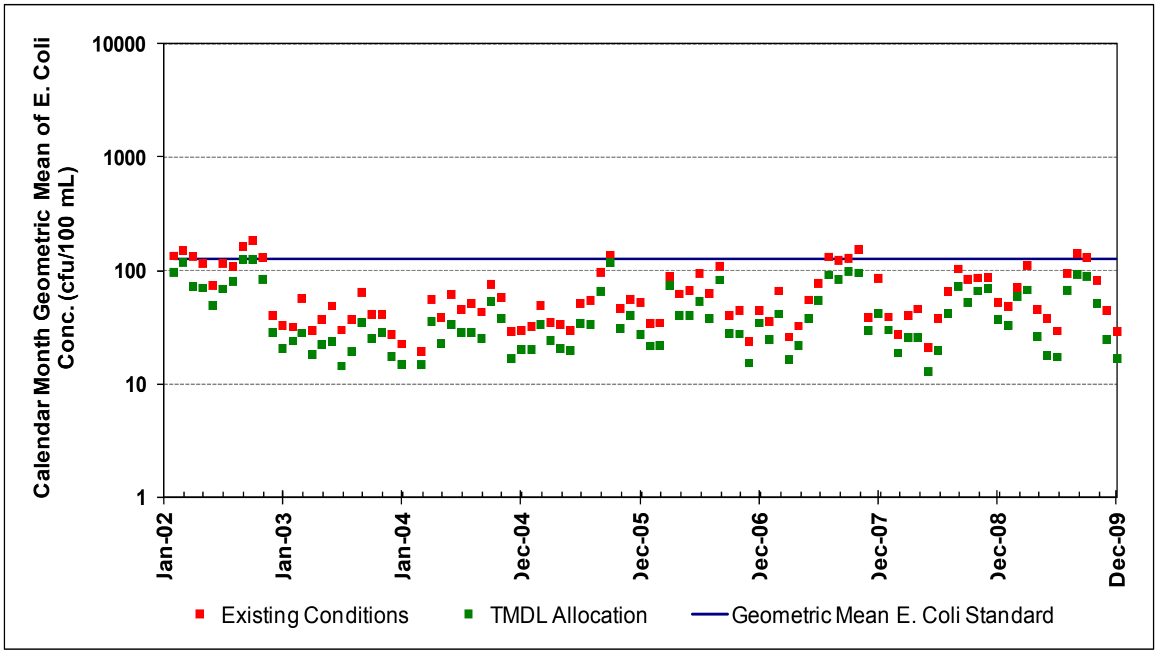

Figure 4- 5: South Fork Quantico Creek Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

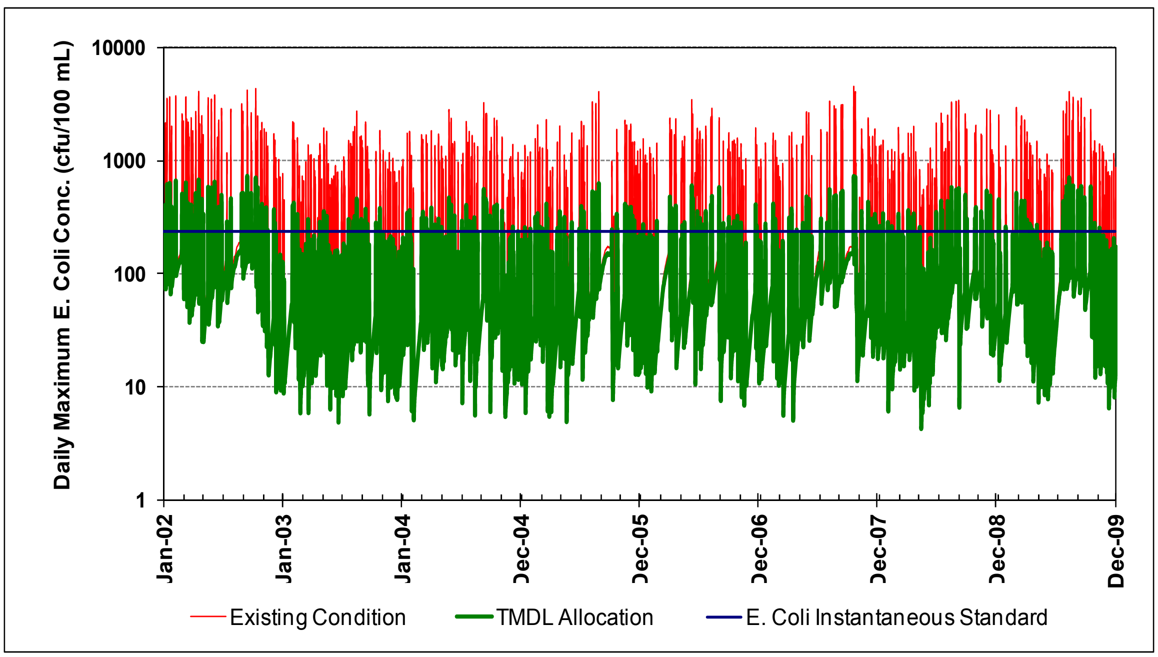

Figure 4- 6: South Fork Quantico Creek Instantaneous *E. coli* Concentrations under Allocation Scenario 13

4.8 North Branch Chopawamsic Creek Allocation Plan and TMDL Summary

As shown in **Table 4-8**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100ml for North Branch Chopawamsic Creek. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 93.6 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 93.6 percent reduction of the indirect loading from wildlife.

Table 4-23 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 23: North Branch Chopawamsic Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	2.60E+13	1.66E+12	93.6%
Cropland	1.98E+09	1.26E+08	93.6%
Pasture	4.15E+08	2.65E+07	93.6%
Urban(1)	5.93E+11	3.79E+10	93.6%
Cattle-Direct Deposition	0.00E+00	0.00E+00	0.0%
Wildlife-Direct Deposition	2.12E+12	2.12E+12	0.0%
Failing Sewage Disposal Systems	0.00E+00	0.00E+00	0.0%
Permitted Point Sources	0.00E+00	3.82E+10	-
Total	**2.87E+13**	**3.86E+12**	**86.6%**

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for North Branch Chopawamsic Creek is presented in **Table 4-24.**

Table 4- 24: North Branch Chopawamsic Creek TMDL (cfu/year) for *E. coli*

Watershed	WLA[1]	LA	MOS	TMDL
North Branch Chopawamsic Creek	**7.36E+10**	**3.78E+12**	**IMPLICIT**	**3.86E+12**

[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for North Branch Chopawamsic Creek is presented in **Table 4-25**.

Table 4- 25: North Branch Chopawamsic Creek TMDL (cfu/day) for *E. coli*

Watershed	WLA[1]	LA	MOS	TMDL
North Branch Chopawamsic Creek	**1.05E+08**	**4.01E+10**	**IMPLICIT**	**4.02E+10**

[1]Wasteload allocation includes allocated load for the future growth of VPDES permitted point sources (1% of total TMDL) and MS4 areas (load attributed to urban non-point sources).

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-7** and **Figure 4-8**. **Figure 4-7** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-8** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For North Branch Chopawamsic Creek, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

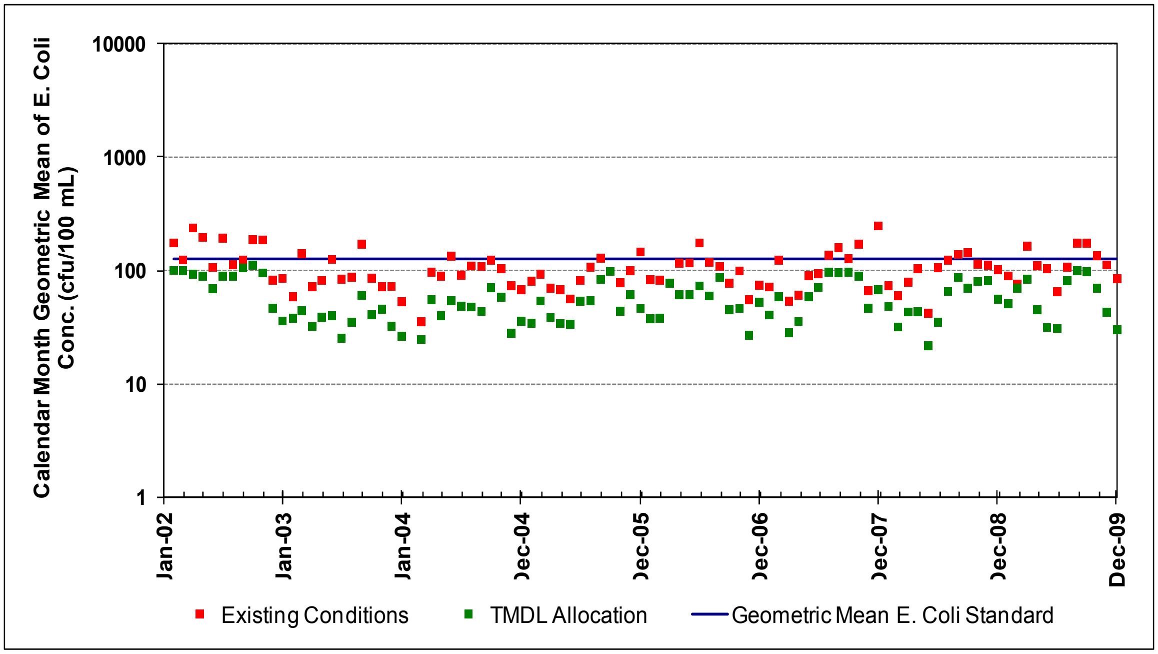

Figure 4- 7: North Branch Chopawamsic Creek Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

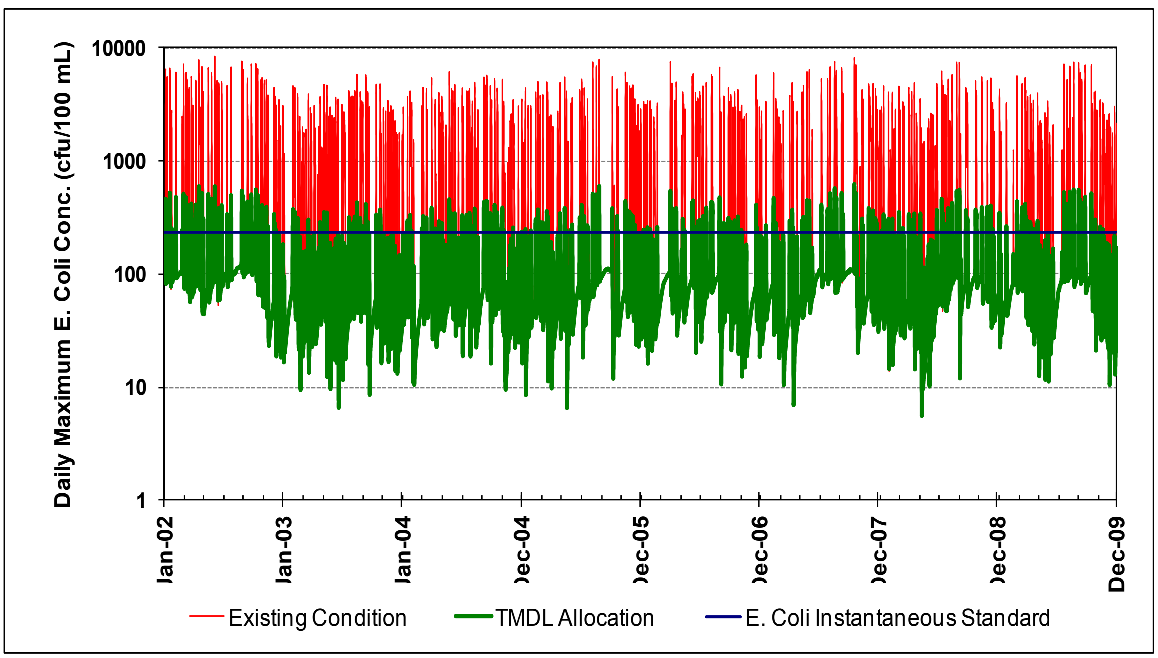

Figure 4- 8: North Branch Chopawamsic Creek Instantaneous *E. coli* Concentrations under Allocation Scenario 13

4.9 Unnamed Tributary to Potomac River Allocation Plan and TMDL Summary

As shown in **Table 4-9**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100ml for Unnamed Tributary to Potomac River. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 94.4 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 94.4 percent reduction of the indirect loading from wildlife.

Table 4-26 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 26: Unnamed Tributary to Potomac River Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	5.17E+12	2.90E+11	94.4%
Cropland	1.70E+09	9.50E+07	94.4%
Pasture	1.07E+09	5.98E+07	94.4%
Urban(1)	3.90E+12	2.19E+11	94.4%
Cattle-Direct Deposition	1.08E+09	0.00E+00	100.0%
Wildlife-Direct Deposition	6.90E+11	6.90E+11	0.0%
Failing Sewage Disposal Systems	7.45E+10	0.00E+00	100.0%
Permitted Point Sources	1.74E+09	1.37E+10	-
Total	**9.84E+12**	**1.21E+12**	**87.7%**

(1)For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for Unnamed Tributary to Potomac River is presented in **Table 4-27.**

Table 4- 27: Unnamed Tributary to Potomac River TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Unnamed Tributary to Potomac River	**2.22E+11**	**9.91E+11**	**IMPLICIT**	**1.21E+12**
[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).				

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for the Unnamed Tributary to Potomac River is presented in **Table 4-28**.

Table 4- 28: Unnamed Tributary to Potomac River TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Unnamed Tributary to Potomac River	**3.28E+07**	**1.20E+10**	**IMPLICIT**	**1.20E+10**
[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).				

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-9** and **Figure 4-10**. **Figure 4-9** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-10** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For Unnamed Tributary to Potomac River, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

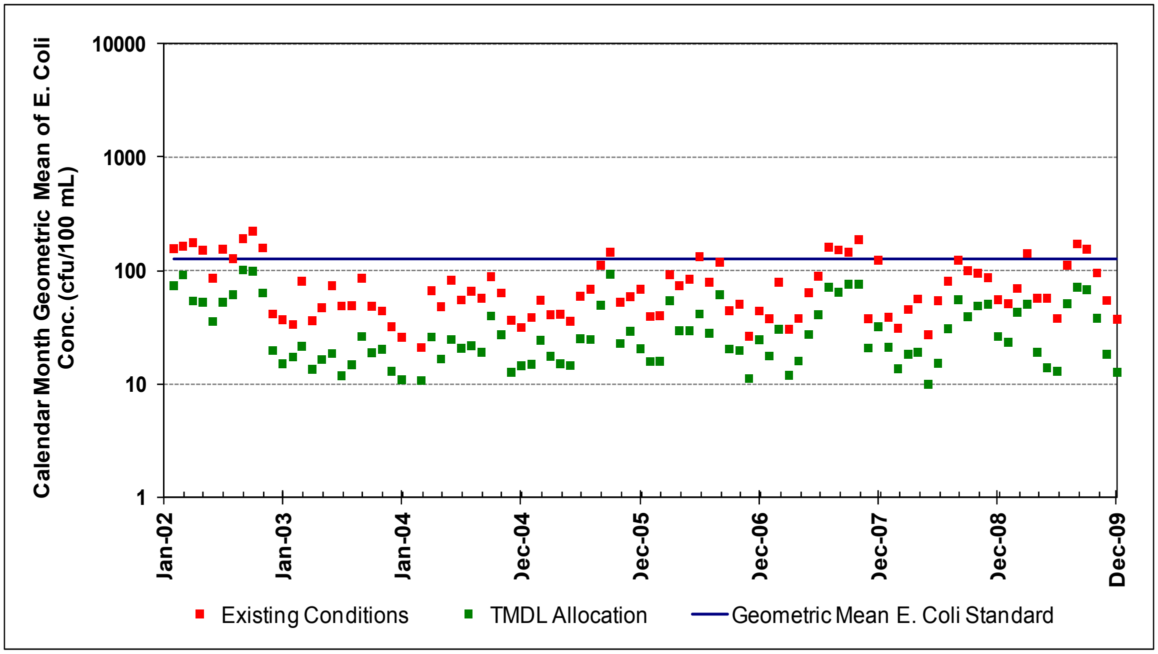

Figure 4- 9: Unnamed Tributary to Potomac River Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

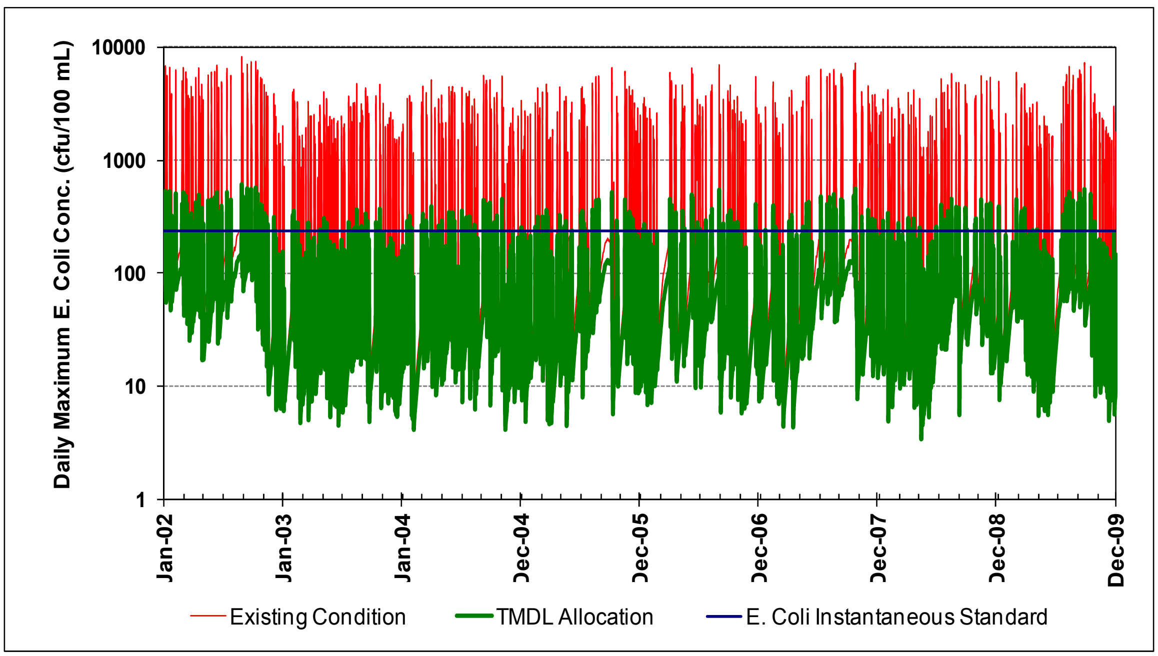

Figure 4- 10: Unnamed Tributary to Potomac River Instantaneous *E. coli* Concentrations under Allocation Scenario 13

4.10 Austin Run Allocation Plan and TMDL Summary

As shown in **Table 4-10**, Scenario 12 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100ml for Austin Run. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 95.9 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 95.9 percent reduction of the indirect loading from wildlife.

Table 4-29 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 29: Austin Run Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	4.33E+13	1.78E+12	95.90%
Cropland	7.42E+09	3.04E+08	95.90%
Pasture	2.88E+09	1.18E+08	95.90%
Urban(1)	3.36E+13	1.38E+12	95.90%
Cattle-Direct Deposition	2.48E+10	0.00E+00	100.00%
Wildlife-Direct Deposition	1.67E+12	1.67E+12	0.00%
Failing Sewage Disposal Systems	1.04E+11	0.00E+00	100.00%
Permitted Point Sources	7.87E+12	3.13E+13	-
Total	**8.66E+13**	**3.62E+13**	**58.2%**

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for Austin Run is presented in **Table 4-30.**

Table 4- 30: Austin Run TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Austin Run	**3.22E+13**	**3.93E+12**	**IMPLICIT**	**3.62E+13**

[1]Wasteload allocation includes the load from VPDES point sources (including the future growth allocation) and the load from MS4 areas (load attributed to urban non-point sources).

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for Austin Run is presented in **Table 4-31**.

Table 4- 31: Austin Run TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Austin Run	**8.74E+10**	**2.10E+10**	**IMPLICIT**	**1.08E+11**

[1]Wasteload allocation includes the load from VPDES permitted point sources (include an allocation for growth) and the load from MS4 areas (load attributed to urban non-point sources)

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-11** and **Figure 4-12**. **Figure 4-11** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 12, as well as geometric mean loading under existing conditions. **Figure 4-12** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 12 as well as the loading under existing conditions. For Austin Run, allocation Scenario 12 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

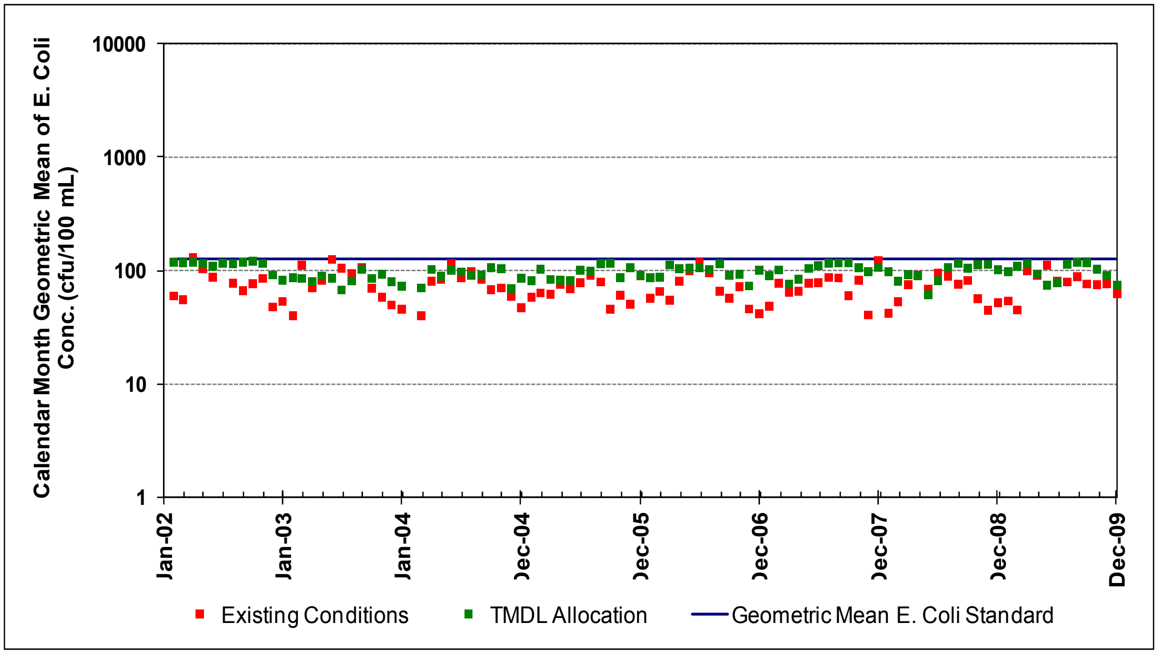

Figure 4- 11: Austin Run Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 12

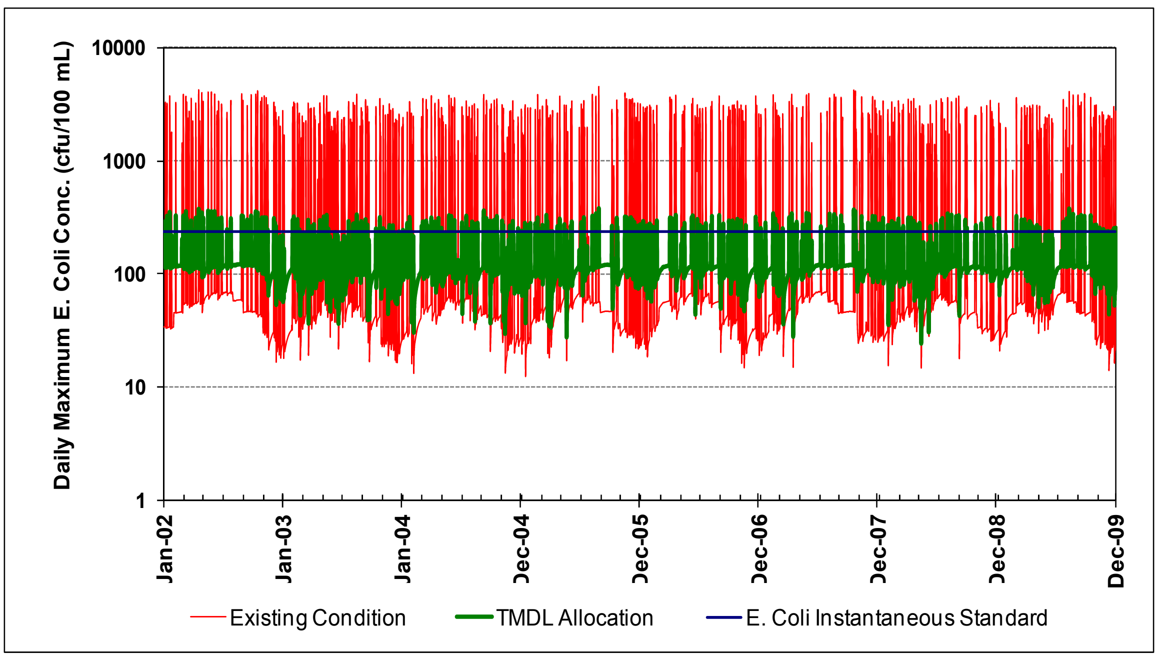

Figure 4- 12: Austin Run Instantaneous *E. coli* Concentrations under Allocation Scenario 12

4.11 Accokeek Creek Allocation Plan and TMDL Summary

As shown in **Table 4-11**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100ml for Accokeek Creek. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 95.5 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 65.5 percent reduction of the indirect loading from wildlife.

Table 4-32 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 32: Accokeek Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	7.24E+12	2.50E+12	65.5%
Cropland	5.52E+11	2.49E+10	95.5%
Pasture	1.01E+13	4.53E+11	95.5%
Urban(1)	4.24E+13	1.91E+12	95.5%
Cattle-Direct Deposition	1.40E+12	0.00E+00	100.0%
Wildlife-Direct Deposition	1.73E+12	1.73E+12	0.0%
Failing Sewage Disposal Systems	1.33E+11	0.00E+00	100.0%
Permitted Point Sources	3.13E+09	6.93E+10	-
Total	**6.36E+13**	**6.69E+12**	**89.5%**

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for Accokeek Creek is presented in **Table 4-33.**

Table 4- 33: Accokeek Creek TMDL (cfu/year) for *E. coli*

Watershed	WLA[1]	LA	MOS	TMDL
Accokeek Creek	2.08E+11	6.48E+12	IMPLICIT	6.69E+12

[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for Accokeek Creek is presented in **Table 4-34**.

Table 4- 34: Accokeek Creek TMDL (cfu/day) for *E. coli*

Watershed	WLA[1]	LA	MOS	TMDL
Accokeek Creek	1.81E+08	6.76E+10	IMPLICIT	6.78E+10

[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-13** and **Figure 4-14**. **Figure 4-13** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-14** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For Accokeek Creek, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

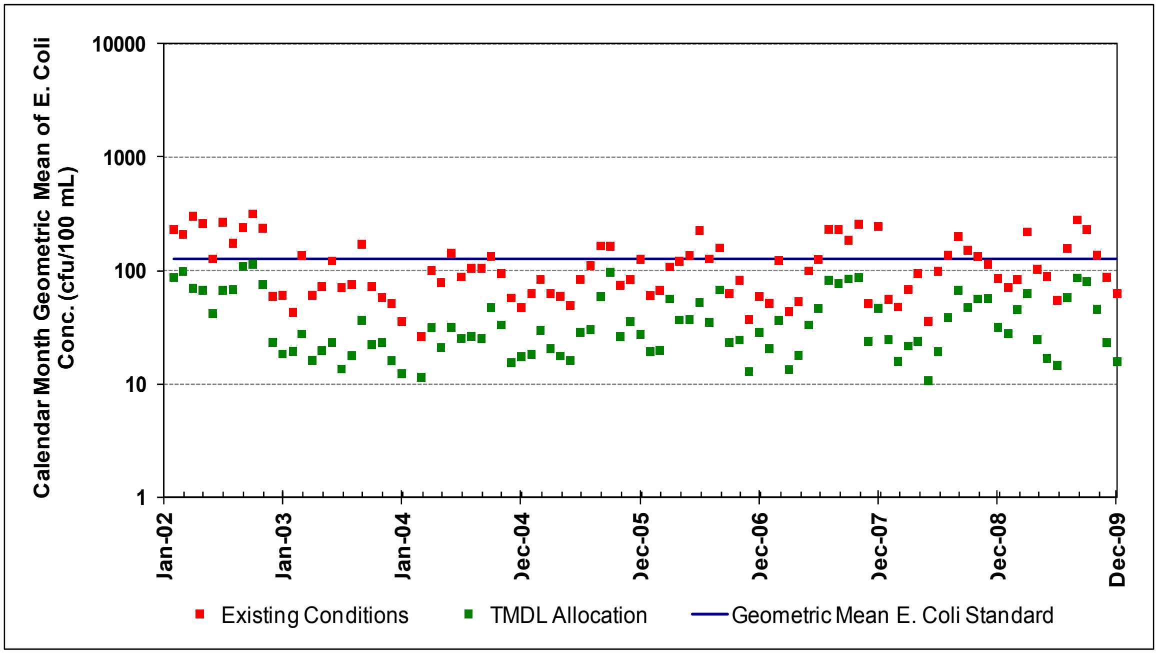

Figure 4- 13: Accokeek Creek Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

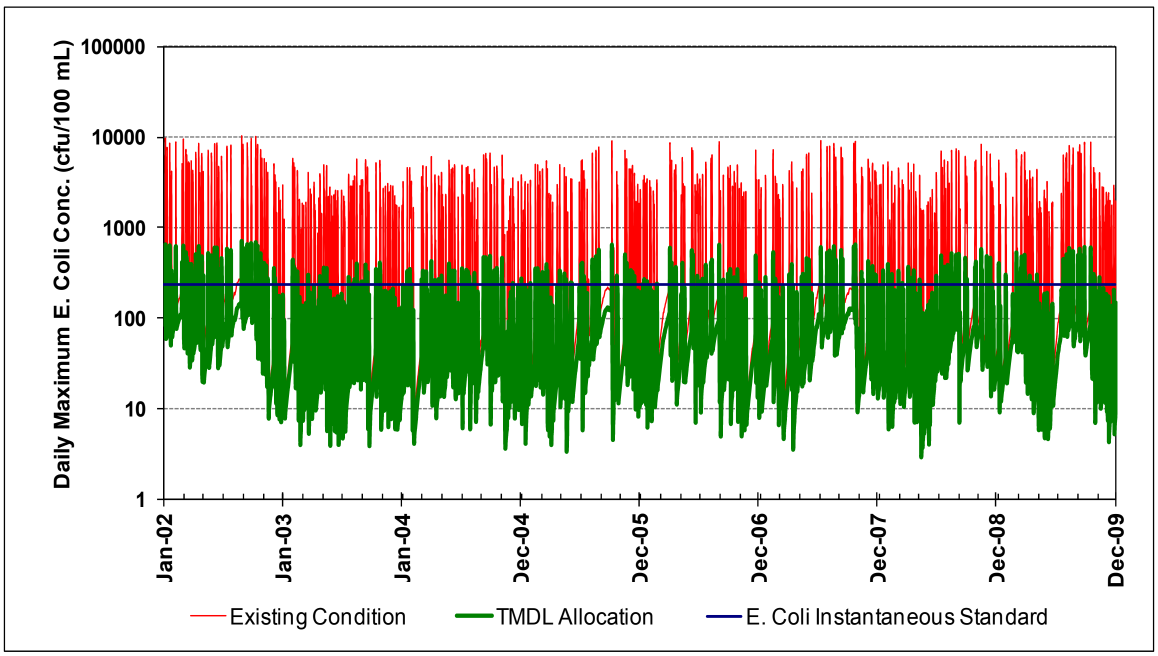

Figure 4- 14: Accokeek Creek Instantaneous *E. coli* Concentrations under Allocation Scenario 13

4.12 Potomac Creek Allocation Plan and TMDL Summary

As shown in **Table 4-12**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100ml for Potomac Creek. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 92.2 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 92.2 percent reduction of the indirect loading from wildlife.

Table 4-35 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 35: Potomac Creek Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	5.61E+13	4.37E+12	92.2%
Cropland	7.27E+12	5.67E+11	92.2%
Pasture	3.26E+13	2.54E+12	92.2%
Urban(1)	4.44E+13	3.46E+12	92.2%
Cattle-Direct Deposition	5.37E+12	0.00E+00	100.0%
Wildlife-Direct Deposition	1.21E+11	1.21E+11	0.0%
Failing Sewage Disposal Systems	2.18E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	1.11E+11	0.0%
Total	**1.46E+14**	**1.12E+13**	**92.4%**

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories

The TMDL for Potomac Creek is presented in **Table 4-36.**

Table 4- 36: Potomac Creek TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Potomac Creek	**1.74E+11**	**1.10E+13**	**IMPLICIT**	**1.12E+13**
[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).				

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for Potomac Creek is presented in **Table 4-37**.

Table 4- 37: Potomac Creek TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Potomac Creek	**3.03E+08**	**1.16E+11**	**IMPLICIT**	**1.16E+11**
[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).				

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-15** and **Figure 4-16**. **Figure 4-15** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-16** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For Potomac Creek, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

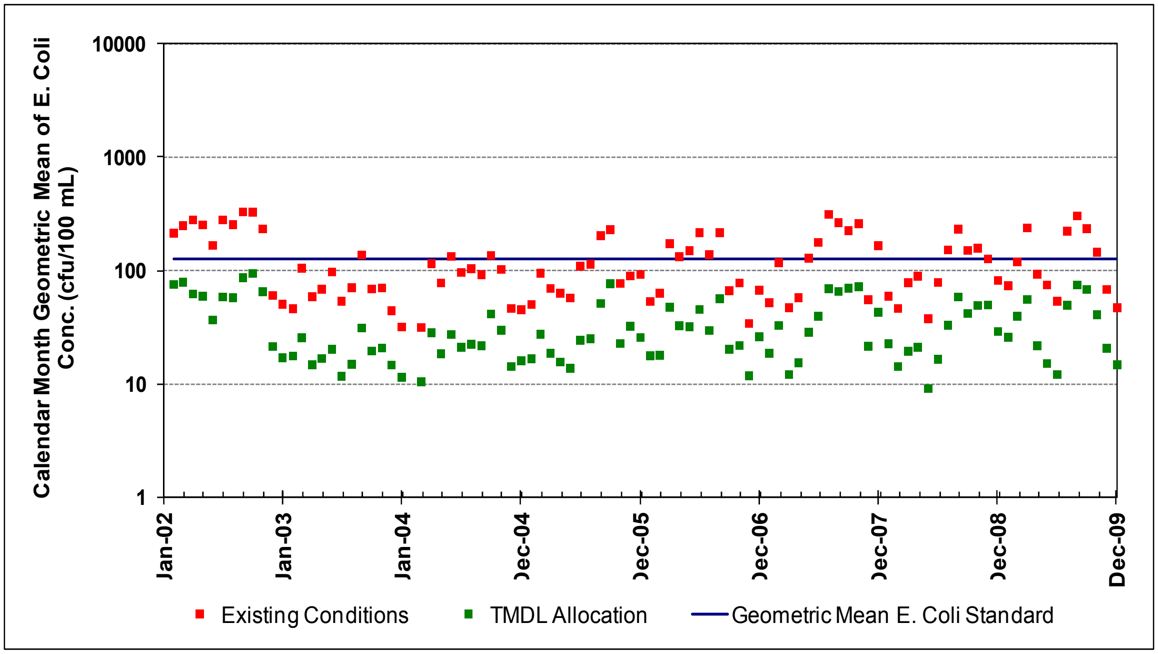

Figure 4- 15: Potomac Creek Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

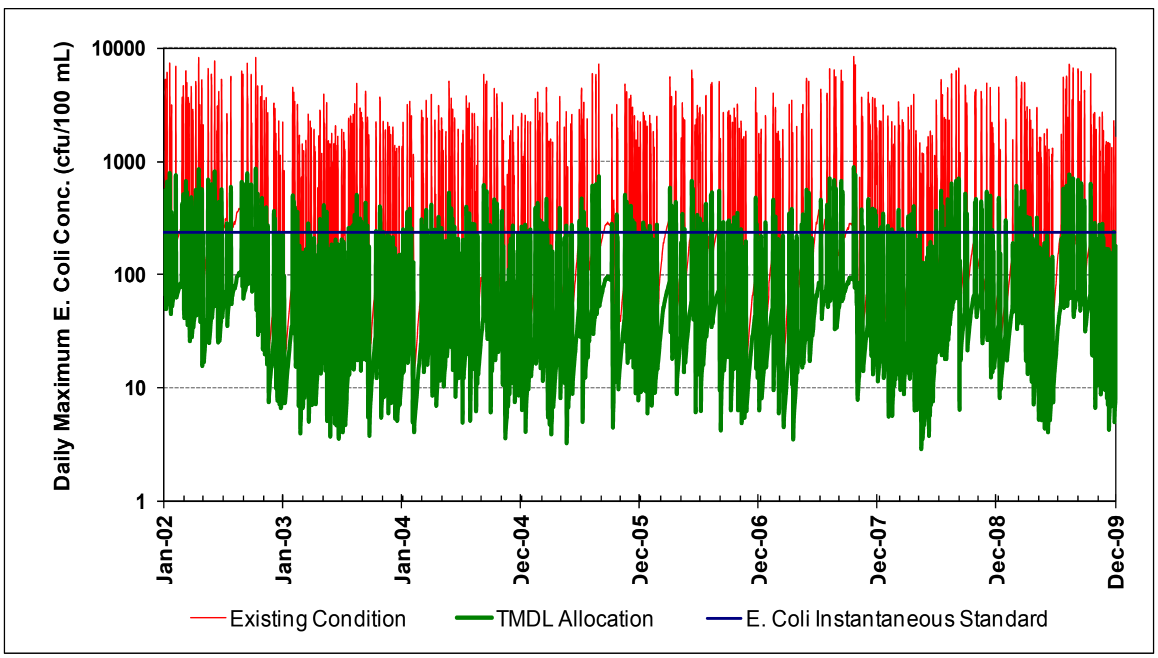

Figure 4- 16: Potomac Creek Instantaneous *E. coli* Concentrations under Allocation Scenario 13

4.13 Potomac Run Allocation Plan and TMDL Summary

As shown in **Table 4-13**, Scenario 13 will meet the calendar-month *E. coli* geometric mean water quality criterion of 126 cfu/100 ml and the maximum assessment water quality criterion of 235 cfu/100ml for Potomac Run. The requirements for this scenario are:

- 100 percent reduction of the human sources (failing sewage disposal systems).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 98 percent reduction of the indirect loading from wildlife.
- 59 percent reduction of the direct loading from wildlife.

Table 4-38 shows the distribution of the annual average *E. coli* load under existing conditions and under the TMDL allocation, by land use and source.

Table 4- 38: Potomac Run Distribution of Annual Average *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average *E. coli* Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	1.31E+13	2.62E+11	98.0%
Cropland	4.14E+12	8.28E+10	98.0%
Pasture	3.64E+13	7.28E+11	98.0%
Urban(1)	2.63E+12	5.26E+10	98.0%
Cattle-Direct Deposition	2.19E+13	0.00E+00	100.0%
Wildlife-Direct Deposition	2.17E+12	8.88E+11	59.0%
Failing Sewage Disposal Systems	2.16E+11	0.00E+00	100.0%
Permitted Point Sources	0.00E+00	2.01E+10	0.0%
Total	8.06E+13	2.03E+12	97.5%

(1) For this TMDL, the load from urban non-point sources was allocated to the MS4 areas, including bacteria loads from Low Density Development, Medium Density Development and High Density Development land use categories.

The TMDL for Potomac Run is presented in **Table 4-39.**

Table 4- 39: Potomac Run TMDL (cfu/year) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Potomac Run	**6.21E+10**	**1.97E+12**	**IMPLICIT**	**2.03E+12**
[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).				

As mentioned in Section 4-3, the long-term average *E. coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the approach outlined in the *USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*.

A summary of the daily TMDL allocation plan loads for Potomac Run is presented in **Table 4-40**.

Table 4- 40: Potomac Run TMDL (cfu/day) for *E. coli*				
Watershed	**WLA[1]**	**LA**	**MOS**	**TMDL**
Potomac Run	**5.52E+07**	**1.93E+10**	**IMPLICIT**	**1.93E+10**
[1]Wasteload allocation includes allocated load for VPDES permitted point sources (including future growth allocation) and MS4 areas (load attributed to urban non-point sources).				

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figures 4-17** and **Figure 4-18**. **Figure 4-17** shows the calendar month geometric mean *E. coli* concentrations after applying the allocations of Scenario 13, as well as geometric mean loading under existing conditions. **Figure 4-18** shows the instantaneous *E. coli* concentrations also under the allocations of Scenario 13 as well as the loading under existing conditions. For Potomac Run, allocation Scenario 13 results in bacteria concentrations that are consistently below both the geometric mean and maximum assessment criterion for *E. coli*.

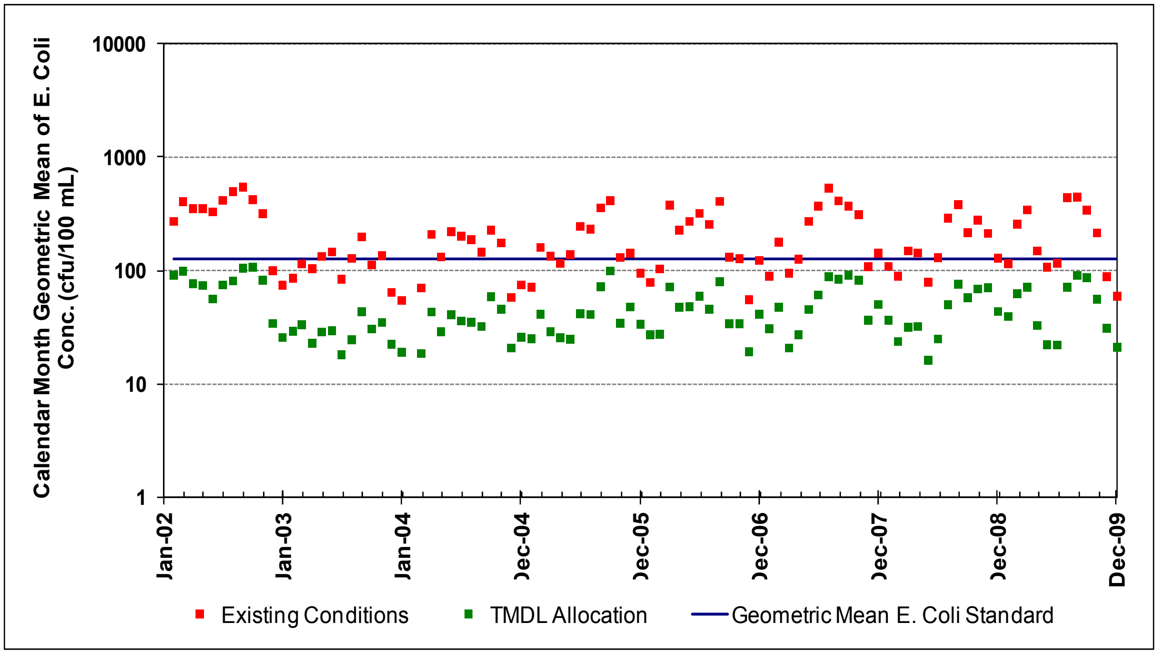

Figure 4- 17: Potomac Run Geometric Mean *E. coli* Concentrations under Existing Conditions and Allocation Scenario 13

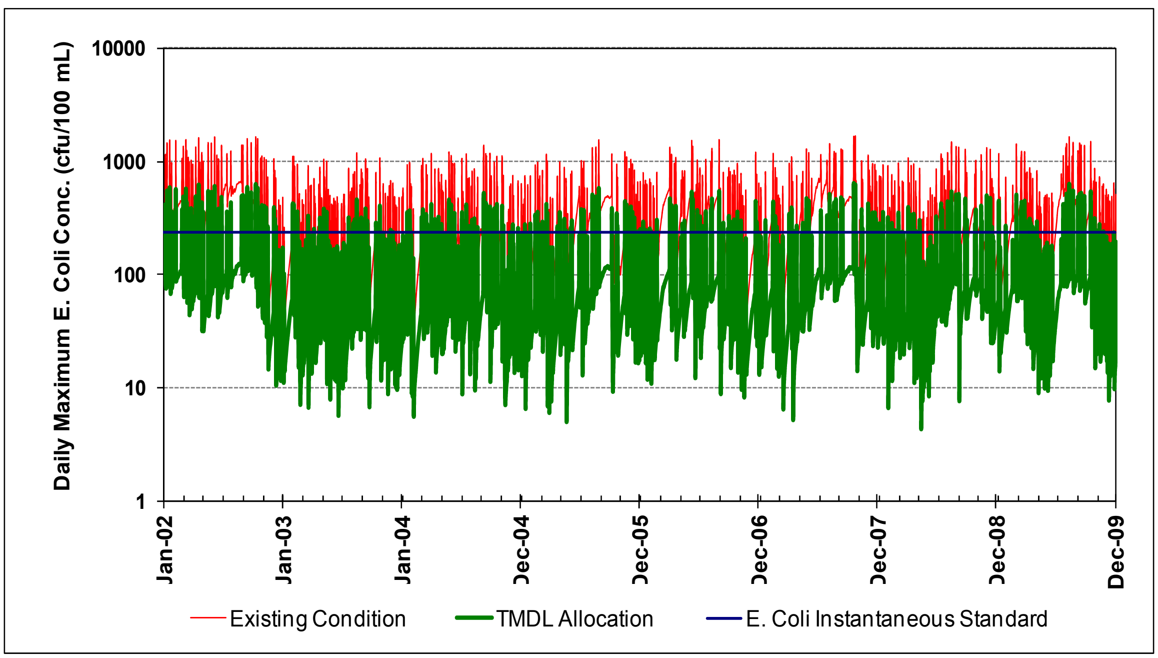

Figure 4- 18: Potomac Run Instantaneous *E. coli* Concentrations under Allocation Scenario 13

5.0 TMDL Implementation and Reasonable Assurance

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non-point sources. The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

5.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

DEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on DEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

5.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring.

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling.

3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements.

4. It helps ensure that the most cost effective practices are implemented first.

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

5.3 Implementation of Waste Load Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program (VPDES Program and the Virginia Stormwater Management Program (VSMP). Requirements of the permit process should not be duplicated in the TMDL process; depending on the type and nature of a point source discharge, it may be addressed through the development of TMDL implementation plans, or it may be addressed solely through the discharge permit. However, it is recognized that implementation plan development may help to coordinate the efforts of permitted sources through the collaborative process involved in development of the plan.

5.3.1 VPDES Permits

This TMDL does not require reductions from individual, municipal treatment plants permitted under the VPDES program (there are three in the watersheds addressed by this TMDL: Aquia Wastewater Treatment Plant: VPDES Permit Number VA0060968;

Abrahms Ct Sewage Treatment Plant: VPDES Permit Number VA0092479; and Randall Sewage Treatment Plant: VPDES Permit Number VA0089630) or from general VPDES permits that discharge the contaminant of concern (only two in this TMDL, located in the Accokeek Creek and Unnamed Tributary to Potomac River watersheds). Such facilities are required to meet the bacteria criterion of the Virginia WQS at the point of discharge as stipulated in their VPDES permit.

5.3.2 Stormwater Permits

DEQ and DCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. DEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while DCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

For Municipal Separate Stormwater Sewer Systems (MS4s) permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the iterative implementation of programmatic BMPs. BMP effectiveness is determined through permittee implementation of an individual control strategy that includes a monitoring program that is sufficient to determine its BMP effectiveness. As stated in EPA's Memorandum on TMDLs and Stormwater Permits, dated November 22, 2002, "The NPDES permits must require the monitoring necessary to assure compliance under the permit limits." Ambient instream monitoring would not be an appropriate means of determining permit compliance. Ambient monitoring would be appropriate to determine if the entire TMDL is being met by all attributed sources. This is in accordance with recent EPA guidance. If future monitoring indicates no improvement in the quality of the regulated discharge, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a permit compliance issue. Any modifications to the TMDL resulting from water quality standards changes would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed as a condition of the MS4 permit. An implementation plan will identify types of corrective action measures and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees will be strongly encouraged to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL. The implementation of the WLAs for MS4 permits will focus on achieving the percent reductions required by the TMDL, rather than the individual numeric WLAs.

Additional information on Virginia's Stormwater program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/vsmp.htm .

5.3.3 TMDL Modifications for New or Expanding Dischargers

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, DEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on DEQ's web site at http://www.deq.virginia.gov/waterguidance/

5.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non-point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

5.4.1 Implementation Plan Development

A TMDL implementation plan will be developed that addresses, at a minimum, the requirements specified in the Code of Virginia, Section 62.1-44.19.7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments." EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of DEQ, DCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

5.4.2 Staged Implementation Scenarios

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for non-point source control. Some examples of effective bacterial BMPs for both urban and rural watersheds are the stream side fencing for cattle farms (rural areas), pet waste clean-up programs (urban and rural areas) and government grant programs available to homeowners with failing septic systems and installation of treatment systems for homeowners currently using straight pipes (predominantly rural areas). Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

VADEQ expects that implementation of the bacteria TMDLs will occur in stages, and that full implementation of the TMDLs is a long-term goal. Implementation efforts will focus on controlling anthropogenic sources. Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and cost effective and reasonable BMPs for non-point source control. Additional information on UAAs is presented in section 6.6, Attainability of Designated Uses.

5.4.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Powells Creek, Quantico Creek, South Fork Quantico Creek, North Branch Chopawamsic Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek, and Potomac Run watersheds. Currently, there are various organizations dedicated to protection and restoration of the watersheds, including the Prince William Conservation Alliance, Friends of Stafford Creeks, and Friends of Quantico Bay. Organizations such as these have proved to be invaluable in the effort to restore water quality in impaired watersheds.

5.4.4 Implementation Funding Sources

The implementation of pollutant reductions from non-regulated non-point sources relies heavily on incentive-based programs, while the funding sources for regulated discharges can be varied depending on the type of discharge. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water

Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

In past years the Water Quality Improvement Fund has become a significant funding stream for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html
and at http://www.dcr.virginia.gov/sw/wqia.htm

5.5 Follow-Up Monitoring

Following the development of the TMDL, DEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring programs. DEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004, during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year. **Table 5-1** provides a summary of the water quality monitoring stations in the Tributaries to the Potomac River: Prince William and Stafford County bacteria impaired watersheds.

Table 5- 1: VA DEQ Water Quality Stations

Station ID	Stream Name
1APOW003.11	Powells Creek
1APOW006.11	Powells Creek
1APOW009.99	Powells Creek
1AQUA004.46	Quantico Creek
1ASOQ003.17	South Fork Quantico Creek
1ASOQ006.73	South Fork Quantico Creek
1ANOR009.87	North Branch Chopawamsic Creek
1AXLF000.13	Unnamed Tributary to Potomac River
1AAUS000.49	Austin Run
1AACC006.13	Accokeek Creek
1APOM006.72	Potomac Creek
1APOM012.24	Potomac Creek
1APOM013.02	Potomac Creek
1APOM013.41	Potomac Creek
1ALOH002.20	Able Lake
1ALOH007.93	Long Branch
1AXLB001.49	Unnamed Tributary to Long Branch
1APOR000.40	Potomac Run

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the Implementation Plan), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in DEQ's standard monitoring plan. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with DEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), DEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc.) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

5.6 Assessing Wildlife Contributions and the Attainability of Designated Uses

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. Virginia and USEPA are not proposing the elimination of natural wildlife to allow for the attainment of water quality standards. However, managing overpopulations of wildlife remains an option available to local stakeholders. During the implementation plan development phase of a TMDL process, and in consultation with a local government or land owner(s), should the Department of Game and Inland Fisheries (VDGIF) determine that a population of resident geese, deer or other wildlife is at "nuisance" levels, measures to reduce such populations may be deemed acceptable if undertaken under the supervision, or issued permit, of the VDGIF or the U.S. Fish and Wildlife Service as appropriate. Additional information on VDGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/.

If water quality standards are not being met, a use attainability analysis (UAA) may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use.

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation.

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place.

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original

condition or to operate the modification in such a way that would result in the attainment of the use.

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection.

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment during this process. Additional information can be obtained at

http://www.deq.virginia.gov/wqs/pdf/WQS05A_1.pdf

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation would be for the reductions of all controllable sources to the maximum extent practicable using the implementation approaches described above. DEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E. provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed."

6.0 Public Participation

The development of the Bacteria TMDLs for Tributaries to the Potomac River: Prince William and Stafford County would not have been possible without public participation. Three technical advisory committee (TAC) meetings and two public meetings were held for this project. The following is a summary of the meetings.

TAC Meeting No. 1: The first TAC meeting was held on March 1, 2011 at the DEQ Northern Regional Office in Woodbridge, Virginia. The purpose of this meeting was to provide information on the steps required in the TMDL process and to explain the types of data used in the development of bacteria TMDLs.

TAC Meeting No. 2: The second TAC meeting was held on September 19, 2011 at the Stafford County Administrative Building Center in Stafford, Virginia. The purpose of this meeting was to discuss the preliminary source assessment for the Powells Creek, Quantico Creek, South Fork Quantico Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run watersheds.

TAC Meeting No. 3: The third TAC meeting was held on January 4, 2012 at the Porter Library in Stafford, Virginia. The purpose of this meeting was to provide information on the model calibration and validation results, as well as the preliminary TMDL bacteria allocation scenarios for Powells Creek, Quantico Creek, South Fork Quantico Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run.

First Round of Public Meetings: Two public meetings were held in the spring of 2011 to introduce the project to the public. The first meeting was held on April 19, 2011 at the Stafford Administration Building Center, Stafford, Virginia. Seven people attended this meeting. The second meeting was held on April 20, 2011 at the A.J. Ferlazzo Auditorium in Woodbridge, Virginia. Nine people attended this meeting. The purpose of both meetings was to introduce the TMDL process to the public and explain the steps required in developing bacteria TMDLs for Powells Creek, Quantico Creek, South Fork Quantico Creek, an Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run. Information regarding the potential bacteria sources in the watershed was also presented. Copies of the presentation were available for the public both at the meetings and on the DEQ website. These meetings were advertised in the *Virginia Register*.

Final Public Meeting: The second public meeting was held on February 1, 2012 at Ferlazzo Auditorium in Woodbridge, Virginia. The purpose of this meeting was to present the final TMDL results for Powells Creek, Quantico Creek, South Fork Quantico Creek, Unnamed Tributary to Potomac River, Austin Run, Accokeek Creek, Potomac Creek and Potomac Run. # people attended the meeting. Copies of the presentation and the draft report were available for the public both at the meeting and through the DEQ website. This meeting was publically noticed in the *Virginia Registrar*. No/# written comments were received during the 30-day comment period.

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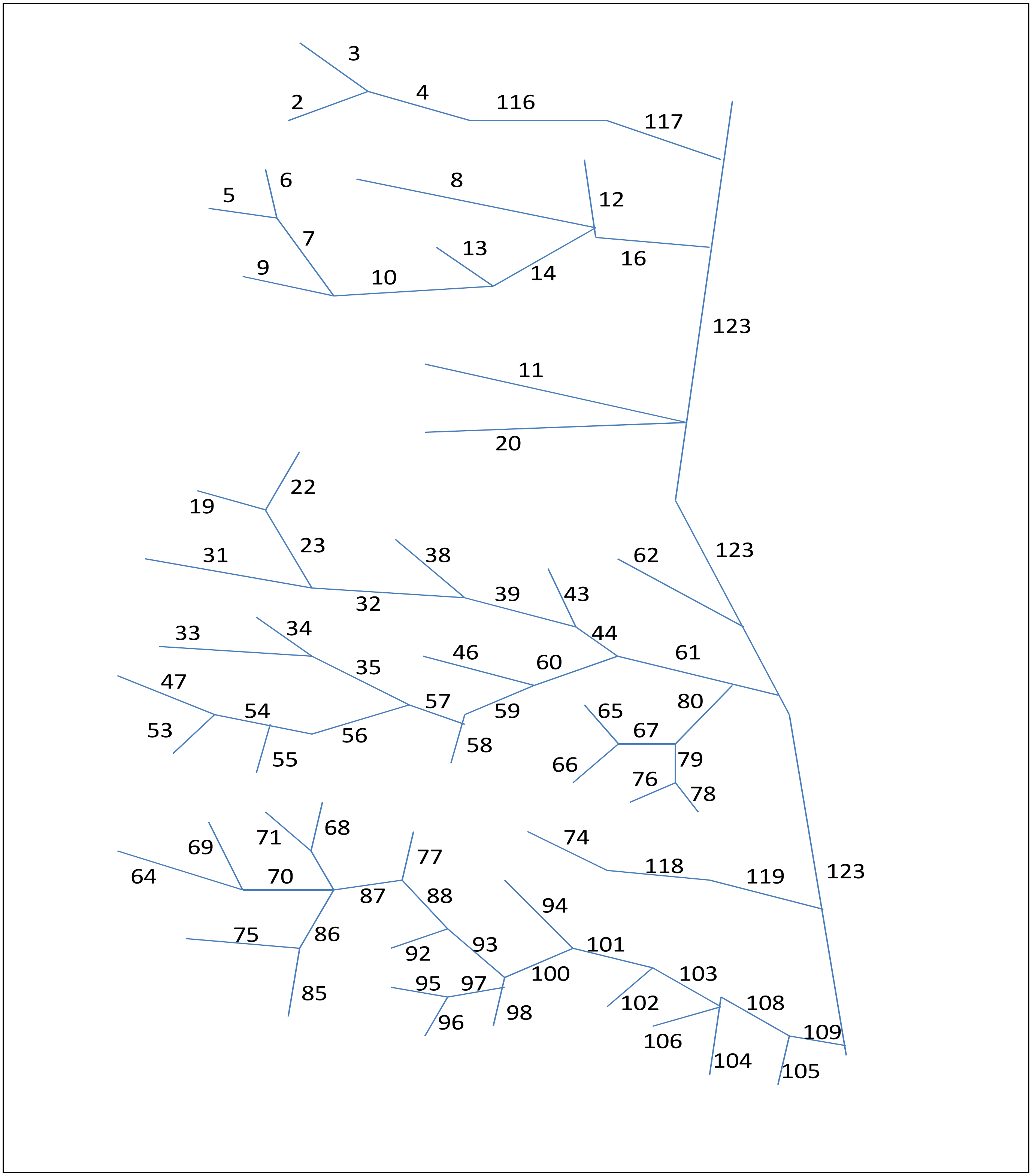
APPENDIX A:

Model Representation of Stream Reach Networks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APPENDIX B:

Monthly Fecal Coliform Build-up Rates and Direct Deposition Loads

Table B- 1: Powells Creek Monthly Build-up Rates (January to June) cfu/ac/day						
Land Use	**Jan**	**Feb**	**Mar**	**April**	**May**	**Jun**
Cropland	4.66E+09	1.32E+10	1.23E+09	2.09E+10	9.79E+09	1.83E+10
Forest	4.66E+09	4.66E+09	4.66E+09	4.66E+09	4.66E+09	4.66E+09
Residential	5.22E+10	5.22E+10	5.22E+10	5.22E+10	5.22E+10	5.22E+10
Pasture	1.66E+11	1.79E+11	1.79E+11	1.95E+11	1.79E+11	1.93E+11

Table B- 2: Powells Creek Monthly Build-up Rates (July to December) cfu/ac/day						
Land Use	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cropland	9.79E+09	1.83E+10	1.23E+10	2.09E+10	1.31E+10	4.66E+09
Forest	4.66E+09	4.66E+09	4.66E+09	4.66E+09	4.66E+09	4.66E+09
Residential	5.22E+10	5.22E+10	5.22E+10	5.22E+10	5.22E+10	5.22E+10
Pasture	1.80E+11	1.94E+11	1.84E+11	1.97E+11	1.84E+11	1.69E+11

Table B- 3: Quantico Creek/South Fork Quantico Creek Monthly Build-up Rates (January to June) cfu/ac/day						
Land Use	**Jan**	**Feb**	**Mar**	**April**	**May**	**Jun**
Cropland	5.20E+09	5.20E+09	5.21E+09	5.22E+09	5.21E+09	5.21E+09
Forest	5.20E+09	5.20E+09	5.20E+09	5.20E+09	5.20E+09	5.20E+09
Residential	8.63E+10	8.63E+10	8.63E+10	8.63E+10	8.63E+10	8.63E+10
Pasture	6.25E+10	6.25E+10	6.26E+10	6.26E+10	6.26E+10	6.26E+10

Table B- 4: Quantico Creek/South Fork Quantico Creek Monthly Build-up Rates (July to December) cfu/ac/day						
Land Use	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cropland	5.21E+09	5.21E+09	5.22E+09	5.21E+09	5.20E+09	5.20E+09
Forest	5.20E+09	5.20E+09	5.20E+09	5.20E+09	5.20E+09	5.20E+09
Residential	8.63E+10	8.63E+10	8.63E+10	8.63E+10	8.63E+10	8.63E+10
Pasture	6.26E+10	6.26E+10	6.26E+10	6.26E+10	6.25E+10	6.25E+10

Table B- 5: North Branch Chopawamsic Creek Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jan	Feb	Mar	April	May	Jun
Cropland	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09
Forest	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09
Residential	2.27E+10	2.27E+10	2.27E+10	2.27E+10	2.27E+10	2.27E+10
Pasture	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09

Table B- 6: North Branch Chopawamsic Creek Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09
Forest	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09
Residential	2.27E+10	2.27E+10	2.27E+10	2.27E+10	2.27E+10	2.27E+10
Pasture	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09	1.09E+09

Table B- 7: Unnamed Tributary to Potomac River Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jan	Feb	Mar	April	May	Jun
Cropland	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08
Forest	6.43E+08	6.43E+08	6.43E+08	6.43E+08	6.43E+08	6.43E+08
Residential	1.25E+09	1.25E+09	1.25E+09	1.25E+09	1.25E+09	1.25E+09
Pasture	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08

Table B- 8: Unnamed Tributary to Potomac River Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08
Forest	6.43E+08	6.43E+08	6.43E+08	6.43E+08	6.43E+08	6.43E+08
Residential	1.25E+09	1.25E+09	1.25E+09	1.25E+09	1.25E+09	1.25E+09
Pasture	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08	6.50E+08

Table B- 9: Austin Run Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jan	Feb	Mar	April	May	Jun
Cropland	8.85E+09	1.06E+10	1.05E+10	1.23E+10	9.93E+09	1.17E+10
Forest	8.91E+09	8.91E+09	8.91E+09	8.91E+09	8.91E+09	8.91E+09
Residential	7.15E+12	7.15E+12	7.15E+12	7.15E+12	7.15E+12	7.15E+12
Pasture	9.25E+10	9.49E+10	9.49E+10	9.76E+10	9.48E+10	9.72E+10

Table B- 10: Austin Run Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	1.42E+09	1.17E+10	1.05E+10	1.23E+10	1.06E+10	8.85E+09
Forest	8.91E+09	8.91E+09	8.91E+09	8.91E+09	8.91E+09	8.91E+09
Residential	7.15E+12	7.15E+12	7.15E+12	7.15E+12	7.15E+12	7.15E+12
Pasture	9.50E+10	9.74E+10	9.57E+10	9.80E+10	9.57E+10	9.30E+10

Table B- 11: Accokeek Creek Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jan	Feb	Mar	April	May	Jun
Cropland	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09
Forest	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09
Residential	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10
Pasture	8.28E+10	8.28E+10	8.28E+10	8.28E+10	8.28E+10	8.28E+10

Table B- 12: Accokeek Creek Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09
Forest	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09	2.24E+09
Residential	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10	2.56E+10
Pasture	8.28E+10	8.28E+10	8.28E+10	8.28E+10	8.28E+10	8.28E+10

Table B- 13: Potomac Creek/Potomac Run Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jan	Feb	Mar	April	May	Jun
Cropland	1.61E+10	1.63E+10	1.63E+10	1.64E+10	1.63E+10	1.64E+10
Forest	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
Residential	1.42E+12	1.42E+12	1.42E+12	1.42E+12	1.42E+12	1.42E+12
Pasture	3.32E+11	3.32E+11	3.32E+11	3.32E+11	3.32E+11	3.32E+11

Table B- 14: Potomac Creek/Potomac Run Monthly Build-up Rates (January to June) cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Cropland	1.63E+10	1.64E+10	1.63E+10	1.64E+10	1.63E+10	1.61E+10
Forest	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10	1.61E+10
Residential	1.42E+12	1.42E+12	1.42E+12	1.42E+12	1.42E+12	1.42E+12
Pasture	3.32E+11	3.32E+11	3.32E+11	3.32E+11	3.32E+11	3.32E+11

Table B- 15: Powells Creek Direct Deposition Rates (cfu/day)

Month	Direct Cattle	Direct Septic	Direct Wildlife
1	6.38E+08	2.34E+11	7.78E+10
2	6.38E+08	2.34E+11	7.78E+10
3	1.06E+09	2.34E+11	7.78E+10
4	1.49E+09	2.34E+11	7.78E+10
5	1.49E+09	2.34E+11	7.78E+10
6	1.91E+09	2.34E+11	7.78E+10
7	1.91E+09	2.34E+11	7.78E+10
8	1.91E+09	2.34E+11	7.78E+10
9	1.49E+09	2.34E+11	7.78E+10
10	1.06E+09	2.34E+11	7.78E+10
11	1.06E+09	2.34E+11	7.78E+10
12	6.38E+08	2.34E+11	7.78E+10

Table B- 16: Quantico Creek/South Fork Quantico Creek Monthly Direct Deposition Rates (cfu/day)

Month	Direct Cattle	Direct Septic	Direct Wildlife
1	8.08E+07	8.85E+10	1.15E+11
2	8.08E+07	8.85E+10	1.15E+11
3	1.27E+08	8.85E+10	1.15E+11
4	1.74E+08	8.85E+10	1.15E+11
5	1.74E+08	8.85E+10	1.15E+11
6	2.20E+08	8.85E+10	1.15E+11
7	2.20E+08	8.85E+10	1.15E+11
8	2.20E+08	8.85E+10	1.15E+11
9	1.74E+08	8.85E+10	1.15E+11
10	1.27E+08	8.85E+10	1.15E+11
11	1.27E+08	8.85E+10	1.15E+11
12	8.08E+07	8.85E+10	1.15E+11

Table B- 17: North Branch Chopawamsic Creek Monthly Direct Deposition Rates (cfu/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	0.00+00	7.01E+06	5.71E+10
2	0.00+00	7.01E+06	5.71E+10
3	0.00+00	7.01E+06	5.71E+10
4	0.00+00	7.01E+06	5.71E+10
5	0.00+00	7.01E+06	5.71E+10
6	0.00+00	7.01E+06	5.71E+10
7	0.00+00	7.01E+06	5.71E+10
8	0.00+00	7.01E+06	5.71E+10
9	0.00+00	7.01E+06	5.71E+10
10	0.00+00	7.01E+06	5.71E+10
11	0.00+00	7.01E+06	5.71E+10
12	0.00+00	7.01E+06	5.71E+10

Table B- 18: Unnamed Tributary to Potomac River Monthly Direct Deposition Rates (cfu/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	6.47E+07	3.13E+08	4.71E+11
2	1.14E+10	3.13E+08	4.71E+11
3	1.81E+10	3.13E+08	4.71E+11
4	2.49E+10	3.13E+08	4.71E+11
5	2.49E+10	3.13E+08	4.71E+11
6	3.16E+10	3.13E+08	4.71E+11
7	3.18E+10	3.13E+08	4.71E+11
8	3.18E+10	3.13E+08	4.71E+11
9	2.50E+10	3.13E+08	4.71E+11
10	1.82E+10	3.13E+08	4.71E+11
11	1.82E+10	3.13E+08	4.71E+11
12	1.15E+10	3.13E+08	4.71E+11

Table B- 19: Austin Run Monthly Direct Deposition Rates (cfu/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	4.09E+08	7.88E+11	1.18E+12
2	4.09E+08	7.88E+11	1.18E+12
3	6.52E+08	7.88E+11	1.18E+12
4	8.96E+08	7.88E+11	1.18E+12
5	8.96E+08	7.88E+11	1.18E+12
6	1.14E+09	7.88E+11	1.18E+12
7	1.32E+09	7.88E+11	1.18E+12
8	1.32E+09	7.88E+11	1.18E+12
9	1.03E+09	7.88E+11	1.18E+12
10	7.54E+08	7.88E+11	1.18E+12
11	7.54E+08	7.88E+11	1.18E+12
12	4.73E+08	7.88E+11	1.18E+12

Table B- 20: Accokeek Creek Monthly Direct Deposition Rates (cfu/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	7.00E+08	2.65E+11	1.07E+11
2	7.00E+08	2.65E+11	1.07E+11
3	1.10E+09	2.65E+11	1.07E+11
4	1.51E+09	2.65E+11	1.07E+11
5	1.51E+09	2.65E+11	1.07E+11
6	1.91E+09	2.65E+11	1.07E+11
7	1.91E+09	2.65E+11	1.07E+11
8	1.91E+09	2.65E+11	1.07E+11
9	1.51E+09	2.65E+11	1.07E+11
10	1.10E+09	2.65E+11	1.07E+11
11	1.10E+09	2.65E+11	1.07E+11
12	7.00E+08	2.65E+11	1.07E+11

Table B- 21: Potomac Creek/Potomac Run Monthly Direct Deposition Rates (cfu/day)			
Month	Direct Cattle	Direct Septic	Direct Wildlife
1	5.39E+09	3.28E+11	2.40E+11
2	5.39E+09	3.28E+11	2.40E+11
3	8.51E+09	3.28E+11	2.40E+11
4	1.16E+10	3.28E+11	2.40E+11
5	1.16E+10	3.28E+11	2.40E+11
6	1.48E+10	3.28E+11	2.40E+11
7	1.48E+10	3.28E+11	2.40E+11
8	1.48E+10	3.28E+11	2.40E+11
9	1.16E+10	3.28E+11	2.40E+11
10	8.51E+09	3.28E+11	2.40E+11
11	8.51E+09	3.28E+11	2.40E+11
12	5.39E+09	3.28E+11	2.40E+11

Appendix C – Abbreviations and Glossary

Abbreviations

AVMA: American Veterinary Medical Association
BMP: Best Management Practice
CWA: Clean Water Act
DEM: Digital Elevation Model
EPA: Environmental Protection Agency
HSPEXP: Expert System for Calibration of the Hydrological Simulation Program-FORTRAN
HSPF: Hydrologic Simulation Program-Fortran
HUC: Hydrologic Unit Code
LA: Load Allocation
MS4: Municipal separate storm sewer system
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Database
NOAA: National Oceanic and Atmospheric Association
NRO: Northern Regional Office
NPDES: National Pollution Discharge Elimination System
NRCS: Natural Resources Conservation Service
MOS: Margin of Safety
SSURGO: Soil Survey Geographic
SWCB: State Water Control Board
SWCD: Soil and Water Conservation District
TAC: Technical Advisory Committee
TMDL: Total Maximum Daily Load
USGS: U.S. Geological Survey
VADCR: Virginia Department of Conservation and Recreation
VADEQ: Virginia Department of Environmental Quality
VADGIF: Virginia Department of Game and Inland Fisheries
VDH: Virginia Department of Health
VDMME: Virginia Department of Mines, Minerals, and Energy
VPDES: Virginia Pollutant Discharge Elimination System
VSMP: Virginia Stormwater Management Program
VT: Virginia Tech
UAA: Use Attainability Analysis
USDA: United States Department of Agriculture
WLA: Wasteload Allocation
WQIF: Water Quality Improvement Fund
WQMIRA: Water Quality Monitoring, Information, and Restoration Act

Glossary

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. That portion of receiving water's loading capacity attributed to one of its existing or future pollution sources (non-point or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future non-point source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)

Ambient water quality. Natural concentration of water quality constituents prior to mixing of either point or non-point source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.

Anthropogenic. Pertains to the [environmental] influence of human activities.

Bacteria. Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Biosolids. Also known as Sewage sludge, is the name for the solid, semisolid, or liquid materials removed during the treatment of domestic sewage in a treatment facility. Biosolids include, but are not limited to, solids removed during primary, secondary, or advanced wastewater treatment, scum, domestic septage, portable toilet pumpings, Type III marine sanitation device pumpings, and sewage sludge products. When properly treated and processed, sewage sludge becomes "biosolids" which can be safely recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth.

Best management practices (BMPs). Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally non-point source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Clean Water Act (CWA). The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.

Concentration. Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).

Contamination. The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.

Cost-share program. A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).

Critical condition. The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.

Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

Domestic wastewater. Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.

Drainage basin. A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.

Existing use. Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Infiltration capacity. The capacity of a soil to allow water to infiltrate into or through it during a storm.

Interflow. Runoff that travels just below the surface of the soil.

Loading, Load, Loading rate. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.

Load allocation (LA). The portion of a receiving waters loading capacity attributed either to one of its existing or future non-point sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and non-point source loads should be distinguished (40 CFR 130.2(g)).

Loading capacity (LC). The greatest amount of loading a water body can receive without violating water quality standards.

Margin of safety (MOS). A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving water body (CWA section 303(d)(1)©). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

Mean. The sum of the values in a data set divided by the number of values in the data set.

Monitoring. Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

Narrative criteria. Non-quantitative guidelines that describe the desired water quality goals.

Non-point source. Pollution that originates from multiple sources over a relatively large area. Non-point sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Numeric targets. A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.

Point source. Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water waterbody or river.

Pollutant. Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Poultry Litter. A material used as bedding in poultry operations. Common litter materials are woodshavings, sawdust, peanut hulls, shredded sugar cane, straw, and other dry, absorbent, low-cost organicmaterials. After use, the litter consists primarily of poultry manure, but also contains the original littermaterial, feathers, and spilled feed.

Privately owned treatment works. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.

Public comment period. The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

Publicly owned treatment works (POTW). Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.
Raw sewage. Untreated municipal sewage.

Receiving waters. Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

Riparian areas. Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.

Riparian zone. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.

Runoff. That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Sewer. A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.

Slope. The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).

Stakeholder. Any person with a vested interest in the TMDL development.

Surface area. The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.

Surface runoff. Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of non-point source pollutants.

Surface water. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.

Topography. The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.

Total Maximum Daily Load (TMDL). The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for non-point sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Virginia Pollutant Discharge Elimination System (NPDES). The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.

Wasteload allocation (WLA). The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).

Wastewater. Usually refers to effluent from a sewage treatment plant. See also **Domestic wastewater**.

Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.

Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

Water quality criteria. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water quality standard. Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

Watershed. A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

WQIA. Water Quality Improvement Act.

APPENDIX D:

NLCD 2006 Landuse Distribution in Modeling Segments

NLCD 2006 Landuse Distribution in Modeling Segments

Stream Segment	Land Use																																						
	Bare Land	% Total	Cultivated Crops	% Total	Deciduous Forest	% Total	Developed, High Intensity	% Total	Developed, Low Intensity	% Total	Developed, Medium Intensity	% Total	Developed, Open Space	% Total	Estuarine Emergent Wetland	% Total	Estuarine Forested Wetland	% Total	Estuarine Scrub/Shrub Wetland	% Total	Evergreen Forest	% Total	Grassland/Herbaceous	% Total	Mixed Forest	% Total	Open Water	% Total	Palustrine Aquatic Bed	% Total	Palustrine Emergent Wetland	% Total	Palustrine Forested Wetland	% Total	Palustrine Scrub/Shrub Wetland	% Total	Pasture/Hay	% Total	Scrub/Shrub	% Total	Unconsolidated Shore	% Total	TOTAL
2	175	8%	37	1%	736	1%	45	5%	59	1%	42	2%	94	2%	0	0%	0	0%	0	0%	64	1%	20	1%	33	0%	0	0%	0	0%	0	0%	83	1%	8	1%	3	0%	71	1%	0	0%	1,470
3	0	0%	60	1%	761	1%	6	1%	77	1%	20	1%	126	2%	0	0%	0	0%	0	0%	34	0%	12	1%	50	1%	1	0%	0	0%	2	0%	72	1%	8	1%	9	0%	52	1%	0	0%	1,289
4	9	0%	203	4%	1,036	2%	41	4%	242	3%	57	3%	132	2%	0	0%	0	0%	0	0%	43	0%	21	1%	44	1%	0	0%	0	0%	3	1%	154	2%	16	3%	52	1%	96	2%	0	0%	2,148
5	0	0%	13	0%	981	2%	0	0%	1	0%	1	0%	2	0%	0	0%	0	0%	0	0%	65	1%	11	1%	73	1%	0	0%	0	0%	1	0%	50	1%	15	2%	0	0%	57	1%	0	0%	1,272
6	0	0%	30	1%	461	1%	4	0%	29	0%	13	1%	54	1%	0	0%	0	0%	0	0%	59	1%	19	1%	43	1%	0	0%	0	0%	0	0%	58	1%	4	1%	8	0%	47	1%	0	0%	829
7	0	0%	0	0%	993	2%	1	0%	2	0%	5	0%	1	0%	0	0%	0	0%	0	0%	190	2%	23	1%	166	2%	0	0%	0	0%	2	1%	174	2%	13	2%	0	0%	18	0%	0	0%	1,588
8	1	0%	9	0%	3,437	5%	57	6%	63	1%	24	1%	49	1%	0	0%	0	0%	0	0%	228	3%	4	0%	261	3%	1	0%	0	0%	1	0%	176	2%	5	1%	2	0%	45	1%	0	0%	4,363
9	0	0%	0	0%	371	1%	0	0%	1	0%	0	0%	0	0%	0	0%	0	0%	0	0%	131	2%	52	3%	76	1%	0	0%	0	0%	6	2%	39	1%	5	1%	0	0%	7	0%	0	0%	688
10	0	0%	5	0%	1,157	2%	0	0%	2	0%	0	0%	11	0%	0	0%	0	0%	0	0%	440	5%	13	1%	962	13%	5	0%	0	0%	1	0%	168	2%	2	0%	2	0%	48	1%	0	0%	2,813
11	0	0%	46	1%	1,866	3%	0	0%	4	0%	2	0%	1	0%	0	0%	0	0%	0	0%	559	6%	57	3%	858	11%	0	0%	0	0%	1	0%	364	5%	46	8%	9	0%	120	2%	0	0%	3,935
12	45	2%	18	0%	687	1%	8	1%	128	2%	38	2%	52	1%	0	0%	0	0%	0	0%	28	0%	5	0%	55	1%	0	0%	0	0%	0	0%	16	0%	2	0%	0	0%	21	0%	1	1%	1,105
13	0	0%	0	0%	286	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	125	1%	0	0%	417	5%	0	0%	0	0%	0	0%	10	0%	1	0%	0	0%	4	0%	0	0%	844
14	0	0%	2	0%	1,727	3%	0	0%	17	0%	3	0%	35	1%	0	0%	0	0%	0	0%	112	1%	1	0%	448	6%	0	0%	0	0%	0	0%	49	1%	0	0%	0	0%	27	1%	0	0%	2,423
16	18	1%	3	0%	351	1%	54	6%	263	4%	146	7%	130	2%	0	0%	0	0%	0	0%	6	0%	7	0%	16	0%	0	0%	0	0%	1	0%	47	1%	0	0%	1	0%	10	0%	0	0%	1,053
19	0	0%	13	0%	1,457	2%	0	0%	1	0%	0	0%	4	0%	0	0%	0	0%	0	0%	116	1%	11	1%	60	1%	0	0%	0	0%	1	0%	246	3%	14	2%	0	0%	102	2%	0	0%	2,026
20	0	0%	5	0%	688	1%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	849	10%	3	0%	967	13%	2	0%	0	0%	1	0%	401	5%	19	3%	0	0%	18	0%	0	0%	2,953
22	0	0%	3	0%	520	1%	0	0%	0	0%	0	0%	1	0%	0	0%	0	0%	0	0%	128	1%	1	0%	58	1%	0	0%	0	0%	0	0%	124	2%	5	1%	0	0%	6	0%	0	0%	845
23	3	0%	17	0%	523	1%	0	0%	19	0%	3	0%	30	1%	0	0%	0	0%	0	0%	288	3%	32	2%	385	5%	211	20%	0	0%	9	3%	127	2%	20	3%	0	0%	48	1%	17	30%	1,734
28	186	8%	3	0%	1,023	2%	31	3%	386	5%	96	4%	366	6%	0	0%	0	0%	0	0%	9	0%	10	1%	37	0%	0	0%	0	0%	2	1%	35	0%	2	0%	9	0%	32	1%	0	0%	2,227
31	1	0%	4	0%	1,001	2%	0	0%	4	0%	0	0%	6	0%	0	0%	0	0%	0	0%	322	4%	55	3%	75	1%	107	10%	0	0%	8	3%	249	3%	18	3%	1	0%	139	3%	7	13%	1,998
32	0	0%	11	0%	994	2%	18	2%	73	1%	31	1%	109	2%	0	0%	0	0%	0	0%	126	1%	15	1%	72	1%	36	3%	0	0%	1	0%	109	1%	7	1%	3	0%	42	1%	4	7%	1,650
33	0	0%	43	1%	1,962	3%	0	0%	3	0%	3	0%	15	0%	0	0%	0	0%	0	0%	545	6%	207	12%	126	2%	5	0%	0	0%	4	1%	293	4%	34	6%	0	0%	558	10%	0	0%	3,798
34	0	0%	0	0%	564	1%	0	0%	1	0%	0	0%	4	0%	0	0%	0	0%	0	0%	60	1%	28	2%	24	0%	0	0%	0	0%	0	0%	39	0%	1	0%	2	0%	126	2%	0	0%	850
35	0	0%	14	0%	1,114	2%	0	0%	3	0%	0	0%	5	0%	0	0%	0	0%	0	0%	310	4%	30	2%	77	1%	0	0%	0	0%	0	0%	100	1%	3	0%	5	0%	27	0%	0	0%	1,688
38	3	0%	27	1%	402	1%	20	2%	75	1%	29	1%	59	1%	0	0%	0	0%	0	0%	135	2%	11	1%	42	1%	2	0%	0	0%	0	0%	40	1%	3	1%	0	0%	17	0%	0	0%	865
39	0	0%	6	0%	483	1%	0	0%	2	0%	0	0%	1	0%	0	0%	0	0%	0	0%	35	0%	0	0%	21	0%	17	2%	0	0%	1	0%	14	0%	1	0%	0	0%	5	0%	0	0%	587
43	1	0%	86	2%	1,054	2%	5	1%	75	1%	17	1%	38	1%	0	0%	0	0%	0	0%	167	2%	17	1%	81	1%	5	0%	0	0%	1	0%	88	1%	11	2%	0	0%	54	1%	0	0%	1,699
44	0	0%	2	0%	147	0%	0	0%	1	0%	0	0%	1	0%	1	1%	0	0%	0	0%	8	0%	0	0%	9	0%	41	4%	0	0%	0	0%	14	0%	1	0%	0	0%	1	0%	1	2%	227
46	0	0%	14	0%	931	1%	2	0%	28	0%	6	0%	45	1%	0	0%	0	0%	0	0%	211	2%	18	1%	54	1%	0	0%	0	0%	1	0%	112	1%	12	2%	0	0%	35	1%	0	0%	1,469
47	1	0%	321	6%	3,422	5%	0	0%	81	1%	2	0%	257	4%	0	0%	0	0%	0	0%	213	2%	36	2%	91	1%	38	4%	0	0%	5	1%	221	3%	29	5%	440	11%	268	5%	0	0%	5,424
53	0	0%	99	2%	329	1%	0	0%	1	0%	0	0%	9	0%	0	0%	0	0%	0	0%	47	1%	11	1%	30	0%	0	0%	0	0%	0	0%	13	0%	3	1%	228	6%	44	1%	0	0%	814
54	0	0%	136	3%	967	1%	1	0%	103	1%	5	0%	165	3%	0	0%	0	0%	0	0%	111	1%	34	2%	59	1%	1	0%	0	0%	0	0%	75	1%	3	0%	176	4%	133	2%	0	0%	1,970
55	0	0%	10	0%	356	1%	0	0%	55	1%	0	0%	45	1%	0	0%	0	0%	0	0%	138	2%	5	0%	25	0%	0	0%	0	0%	0	0%	22	0%	0	0%	9	0%	44	1%	0	0%	709

NLCD 2006 Landuse Distribution in Modeling Segments

Stream Segment	Land Use																																										
	Bare Land	% Total	Cultivated Crops	% Total	Deciduous Forest	% Total	Developed, High Intensity	% Total	Developed, Low Intensity	% Total	Developed, Medium Intensity	% Total	Developed, Open Space	% Total	Estuarine Emergent Wetland	% Total	Estuarine Forested Wetland	% Total	Estuarine Scrub/Shrub Wetland	% Total	Evergreen Forest	% Total	Grassland/Herbaceous	% Total	Mixed Forest	% Total	Open Water	% Total	Palustrine Aquatic Bed	% Total	Palustrine Emergent Wetland	% Total	Palustrine Forested Wetland	% Total	Palustrine Scrub/Shrub Wetland	% Total	Pasture/Hay	% Total	Scrub/Shrub	% Total	Unconsolidated Shore	% Total	TOTAL
56	0	0%	44	1%	684	1%	0	0%	48	1%	21	1%	96	2%	0	0%	0	0%	0	0%	53	1%	24	1%	23	0%	1	0%	0	0%	1	0%	29	0%	1	0%	28	1%	43	1%	0	0%	1,097
57	0	0%	5	0%	54	0%	0	0%	9	0%	12	1%	1	0%	0	0%	0	0%	0	0%	17	0%	4	0%	3	0%	0	0%	0	0%	0	0%	14	0%	2	0%	0	0%	8	0%	0	0%	130
58	25	1%	41	1%	451	1%	10	1%	423	6%	68	3%	223	4%	0	0%	0	0%	0	0%	36	0%	45	3%	21	0%	1	0%	0	0%	0	0%	12	0%	4	1%	34	1%	52	1%	0	0%	1,445
59	234	10%	12	0%	877	1%	19	2%	181	3%	37	2%	102	2%	0	0%	0	0%	0	0%	120	1%	43	2%	45	1%	0	0%	0	0%	0	0%	13	0%	1	0%	53	1%	43	1%	0	0%	1,781
60	41	2%	2	0%	1,041	2%	20	2%	303	4%	107	5%	197	3%	1	1%	0	0%	0	0%	85	1%	23	1%	62	1%	93	9%	0	0%	3	1%	56	1%	1	0%	7	0%	64	1%	2	3%	2,108
61	98	4%	101	2%	1,476	2%	69	7%	612	8%	158	7%	326	6%	59	56%	0	0%	0	0%	97	1%	39	2%	109	1%	107	10%	0	####	90	28%	482	6%	14	2%	10	0%	124	2%	2	4%	3,975
62	21	1%	39	1%	1,845	3%	0	0%	114	2%	10	0%	126	2%	2	2%	0	0%	0	0%	78	1%	18	1%	105	1%	11	1%	0	0%	1	0%	137	2%	12	2%	24	1%	101	2%	3	6%	2,647
64	2	0%	416	8%	1,144	2%	0	0%	2	0%	1	0%	24	0%	0	0%	0	0%	0	0%	163	2%	46	3%	57	1%	1	0%	0	0%	1	0%	69	1%	18	3%	704	18%	159	3%	0	0%	2,808
65	0	0%	0	0%	235	0%	109	12%	538	7%	229	10%	205	3%	0	0%	0	0%	0	0%	8	0%	9	1%	13	0%	0	0%	0	0%	0	0%	14	0%	2	0%	4	0%	45	1%	0	0%	1,413
66	69	3%	25	0%	442	1%	9	1%	476	7%	111	5%	287	5%	0	0%	0	0%	0	0%	71	1%	23	1%	32	0%	0	0%	0	0%	0	0%	47	1%	1	0%	9	0%	70	1%	0	0%	1,671
67	1	0%	0	0%	102	0%	23	2%	121	2%	57	3%	31	1%	0	0%	0	0%	0	0%	0	0%	3	0%	4	0%	0	0%	0	0%	0	0%	20	0%	8	1%	0	0%	12	0%	0	0%	382
68	48	2%	131	2%	426	1%	2	0%	33	0%	5	0%	41	1%	0	0%	0	0%	0	0%	82	1%	23	1%	24	0%	12	1%	0	0%	2	0%	18	0%	2	0%	63	2%	73	1%	1	2%	985
69	1	0%	272	5%	386	1%	0	0%	0	0%	0	0%	10	0%	0	0%	0	0%	0	0%	64	1%	8	0%	19	0%	1	0%	0	0%	1	0%	49	1%	5	1%	231	6%	37	1%	0	0%	1,083
70	0	0%	58	1%	230	0%	0	0%	1	0%	0	0%	15	0%	0	0%	0	0%	0	0%	27	0%	9	1%	14	0%	0	0%	0	0%	0	0%	73	1%	1	0%	145	4%	29	1%	0	0%	604
71	1	0%	128	2%	358	1%	0	0%	3	0%	0	0%	7	0%	0	0%	0	0%	0	0%	51	1%	17	1%	21	0%	0	0%	0	0%	0	0%	20	0%	10	2%	76	2%	67	1%	0	0%	759
72	0	0%	60	1%	77	0%	0	0%	11	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	1	0%	2	0%	0	0%	0	0%	0	0%	8	0%	0	0%	107	3%	9	0%	0	0%	276
74	34	2%	292	5%	2,525	4%	9	1%	369	5%	74	3%	445	8%	0	0%	0	0%	0	0%	299	3%	109	6%	175	2%	10	1%	0	0%	4	1%	257	3%	12	2%	216	5%	262	5%	0	0%	5,092
75	1	0%	69	1%	707	1%	0	0%	3	0%	2	0%	188	3%	0	0%	0	0%	0	0%	86	1%	22	1%	43	1%	75	7%	0	0%	4	1%	57	1%	8	1%	154	4%	55	1%	1	1%	1,474
76	97	4%	40	1%	730	1%	1	0%	45	1%	10	0%	39	1%	0	0%	0	0%	0	0%	56	1%	15	1%	45	1%	0	0%	0	0%	0	0%	21	0%	8	1%	30	1%	36	1%	1	2%	1,173
77	63	3%	65	1%	598	1%	2	0%	15	0%	3	0%	28	0%	0	0%	0	0%	0	0%	75	1%	40	2%	25	0%	0	0%	0	0%	0	0%	16	0%	2	0%	105	3%	54	1%	0	0%	1,091
78	73	3%	32	1%	450	1%	20	2%	129	2%	52	2%	47	1%	0	0%	0	0%	0	0%	27	0%	5	0%	22	0%	0	0%	0	0%	0	0%	29	0%	2	0%	6	0%	16	0%	0	0%	909
79	14	1%	7	0%	40	0%	0	0%	20	0%	5	0%	7	0%	0	0%	0	0%	0	0%	0	0%	1	0%	1	0%	0	0%	0	0%	0	0%	23	0%	3	1%	0	0%	5	0%	0	0%	128
80	54	2%	77	1%	326	1%	16	2%	259	4%	78	4%	146	2%	4	4%	0	0%	0	0%	12	0%	36	2%	17	0%	12	1%	0	0%	31	9%	75	1%	7	1%	17	0%	39	1%	0	0%	1,207
85	0	0%	213	4%	726	1%	0	0%	3	0%	2	0%	18	0%	0	0%	0	0%	0	0%	94	1%	34	2%	35	0%	0	0%	0	0%	0	0%	49	1%	3	1%	86	2%	31	1%	0	0%	1,293
86	0	0%	45	1%	568	1%	0	0%	35	0%	1	0%	11	0%	0	0%	0	0%	0	0%	34	0%	15	1%	15	0%	1	0%	0	0%	0	0%	32	0%	0	0%	73	2%	29	1%	0	0%	859
87	0	0%	26	0%	585	1%	0	0%	23	0%	0	0%	3	0%	0	0%	0	0%	0	0%	44	1%	1	0%	26	0%	0	0%	0	0%	0	0%	13	0%	0	0%	13	0%	42	1%	0	0%	776
88	0	0%	109	2%	421	1%	1	0%	4	0%	1	0%	44	1%	0	0%	0	0%	0	0%	106	1%	54	3%	30	0%	0	0%	0	0%	0	0%	18	0%	1	0%	43	1%	74	1%	0	0%	906
92	0	0%	191	4%	591	1%	0	0%	1	0%	0	0%	20	0%	0	0%	0	0%	0	0%	48	1%	16	1%	37	0%	1	0%	0	0%	1	0%	20	0%	2	0%	171	4%	74	1%	0	0%	1,173
93	0	0%	57	1%	953	1%	0	0%	3	0%	2	0%	55	1%	0	0%	0	0%	0	0%	166	2%	8	0%	83	1%	109	10%	0	0%	9	3%	50	1%	1	0%	32	1%	128	2%	2	3%	1,658
94	285	13%	96	2%	601	1%	32	3%	44	1%	64	3%	186	3%	0	0%	0	0%	0	0%	68	1%	22	1%	41	1%	7	1%	0	0%	1	0%	34	0%	7	1%	18	0%	138	3%	1	2%	1,646
95	0	0%	94	2%	563	1%	0	0%	4	0%	0	0%	12	0%	0	0%	0	0%	0	0%	5	0%	11	1%	7	0%	0	0%	0	0%	0	0%	8	0%	1	0%	76	2%	75	1%	0	0%	856
96	0	0%	106	2%	386	1%	0	0%	17	0%	0	0%	7	0%	0	0%	0	0%	0	0%	7	0%	7	0%	10	0%	0	0%	0	0%	0	0%	2	0%	0	0%	120	3%	76	1%	0	0%	738

NLCD 2006 Landuse Distribution in Modeling Segments

Stream Segment	Land Use																																										
	Bare Land	% Total	Cultivated Crops	% Total	Deciduous Forest	% Total	Developed, High Intensity	% Total	Developed, Low Intensity	% Total	Developed, Medium Intensity	% Total	Developed, Open Space	% Total	Estuarine Emergent Wetland	% Total	Estuarine Forested Wetland	% Total	Estuarine Scrub/Shrub Wetland	% Total	Evergreen Forest	% Total	Grassland/Herbaceous	% Total	Mixed Forest	% Total	Open Water	% Total	Palustrine Aquatic Bed	% Total	Palustrine Emergent Wetland	% Total	Palustrine Forested Wetland	% Total	Palustrine Scrub/Shrub Wetland	% Total	Pasture/Hay	% Total	Scrub/Shrub	% Total	Unconsolidated Shore	% Total	TOTAL
97	0	0%	32	1%	369	1%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	12	0%	0	0%	15	0%	8	1%	0	0%	1	0%	6	0%	0	0%	0	0%	33	1%	0	0%	475
98	2	0%	41	1%	526	1%	0	0%	11	0%	0	0%	22	0%	0	0%	0	0%	0	0%	64	1%	19	1%	34	0%	18	2%	0	0%	2	1%	13	0%	0	0%	60	2%	77	1%	0	1%	889
100	0	0%	58	1%	567	1%	5	1%	12	0%	16	1%	27	0%	0	0%	0	0%	0	0%	129	1%	11	1%	54	1%	5	1%	0	0%	0	0%	42	1%	2	0%	27	1%	81	2%	0	0%	1,036
101	74	3%	136	3%	1,017	2%	155	17%	134	2%	83	4%	77	1%	0	0%	0	0%	0	0%	31	0%	24	1%	52	1%	0	0%	0	0%	1	0%	407	5%	28	5%	17	0%	121	2%	0	0%	2,358
102	0	0%	145	3%	617	1%	1	0%	51	1%	10	0%	59	1%	0	0%	0	0%	0	0%	16	0%	15	1%	24	0%	5	0%	0	0%	0	0%	55	1%	5	1%	59	1%	63	1%	0	0%	1,124
103	7	0%	65	1%	431	1%	2	0%	5	0%	2	0%	11	0%	0	0%	0	0%	0	0%	30	0%	8	0%	37	0%	1	0%	0	0%	2	1%	238	3%	23	4%	16	0%	93	2%	0	0%	971
104	0	0%	64	1%	468	1%	0	0%	10	0%	0	0%	47	1%	0	0%	0	0%	0	0%	39	0%	10	1%	29	0%	2	0%	0	0%	1	0%	83	1%	5	1%	12	0%	49	1%	7	13%	828
105	0	0%	59	1%	489	1%	0	0%	1	0%	0	0%	3	0%	0	0%	0	0%	0	0%	12	0%	7	0%	27	0%	0	0%	0	0%	1	0%	54	1%	9	1%	18	0%	38	1%	0	0%	717
106	38	2%	63	1%	640	1%	1	0%	76	1%	6	0%	82	1%	0	0%	0	0%	0	0%	46	1%	16	1%	43	1%	0	0%	0	0%	1	0%	80	1%	11	2%	35	1%	48	1%	0	0%	1,188
108	8	0%	215	4%	1,092	2%	0	0%	10	0%	6	0%	60	1%	0	0%	0	0%	0	0%	69	1%	18	1%	66	1%	1	0%	0	0%	103	32%	271	4%	31	5%	39	1%	76	1%	0	0%	2,066
109	0	0%	17	0%	262	0%	0	0%	0	0%	0	0%	1	0%	30	28%	0	0%	0	0%	0	0%	0	0%	12	0%	8	1%	0	0%	2	1%	202	3%	4	1%	2	0%	6	0%	0	0%	545
116	11	1%	38	1%	678	1%	28	3%	730	10%	167	7%	317	5%	5	5%	0	0%	0	0%	33	0%	18	1%	53	1%	85	8%	0	0%	5	2%	47	1%	4	1%	10	0%	37	1%	1	2%	2,267
117	441	19%	9	0%	767	1%	51	5%	314	4%	201	9%	122	2%	0	0%	0	0%	0	0%	9	0%	9	1%	31	0%	0	0%	0	0%	0	0%	124	2%	3	1%	15	0%	41	1%	0	0%	2,137
118	83	4%	233	4%	2,115	3%	51	5%	194	3%	76	3%	156	3%	0	0%	0	0%	0	0%	167	2%	65	4%	152	2%	0	0%	0	0%	0	0%	320	4%	14	2%	13	0%	195	4%	3	5%	3,837
119	1	0%	69	1%	1,275	2%	2	0%	19	0%	4	0%	104	2%	0	0%	0	0%	0	0%	29	0%	21	1%	66	1%	10	1%	0	0%	1	0%	243	3%	4	1%	50	1%	62	1%	0	0%	1,960
TOTAL	2,270		5,339		64,699		932		7,215		2,225		5,881		105		0		0		8,667		1,740		7,657		1,059		0		327		7,735		593		3,984		5,412		56		125,897
% of Total	2%		4%		51%		1%		5%		2%		4%		1%		0%		0%		6%		1%		6%		3%		0%		0%		6%		0%		3%		4%		0%		100%